

PREFACE

Chronology is closely connected with history and archæology. The great importance of archaeological research has been acknowledged by most of the advanced nations. The Indian Government has created a special department of Archaeology for the discovery and preservation of the ancient relics of Indian arts and architecture. From the ruins of ancient cities now lying buried under ground old inscriptions tablets coins copper plates vases monuments etc. are being unearthed every year and the work of comparing and verifying their dates so as to fix their chronological place has vastly increased.

Books on Indian Chronology written and published under Government patronage by scholars like Messrs Warren Sewell and Pillai are at present available. But it may be said of them without disparagement that they are much above the reach and comprehension of the class of average students. An elementary book written on the lines of Science Primers explaining with clearness the first principles of chronology and gradually leading the reader to a

thorough understanding of the mathematical and astronomical theory of chronology is, we believe, a desideratum, and the present book is written with the object of removing it

The first three chapters are devoted to the explanation of Eras, the natural units of time and the importance of personal observation of stars and of the movements of the Sun and Moon among them. Chapter IV is intended to illustrate and fix the ideas about the five chief parts of the Hindu Panchānga. Chapter V explains the cause and the effects of the variable motions of the Sun and Moon on their ending times. Chapter VI proves conclusively the astonishing identity of the ancient and modern inequalities of the Sun and Moon. Chapters VII and VIII contain the definitions of the technical terms and the theory of the *Adhika* and *Kshaya* months.

The calculation of the luni-solar Calendar begins with Chapter IX. The next four chapters treat of the calculation of the Solar, Musliman, and Christian Calendars and of the *Samvats* of Northern India. Chapter XIV contains brief sketches of the Vedic, the Chinese, the Jewish and Ecclesiastical Calendars. Chapter XV and XVI treat of the Lunar and Solar Eclipses and of the various kinds of Time. Chapter XVII is intended for advanced readers and contains miscellaneous notes relating to theory, comment, and antiquarian research. The last Chapter XVIII is devoted to Bibliography and is followed by tables and a full Index.

It now remains to thank friends and well-wishers for their advice and help. My most hearty thanks are due to Prof. R. Zimmermann of St. Xavier's College, Bombay; and to Mr. P. V. Kane, M.A., High Court Pleader, Bombay, for valuable suggestions which have considerably added to the utility of this book; and also to Mr. D. V. Apte, B.A., of Hangandi for information regarding the intricate system of Chronology adopted in the official correspondence during the Maratha Period

It is impossible for me to express fully my thankfulness to the Bombay Branch of the Royal Asiatic Society which has, no doubt, done important service to Archaeology by undertaking to print and publish this book of mine, the like of which has, so far as I know, never before appeared in print in this Presidency.

BELGAUM,
11th October 1921

V. B. KETKAR,
Author.

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INDIAN AND FOREIGN CHRONOLOGY

LUNI SOLAR, SOLAR AND LUNAR

(B C 3102 to A D 2100)

CHAPTER I

INTRODUCTORY

THE ERAS TABLE I

CHRONOLOGY is the science of ascertaining the exact moment of the time in days months and years of a particular Era when any past event actually took place. It is, therefore, closely connected with History and Astronomy. Time may be compared to an imaginary straight line, or to a high way of which we can see neither the beginning nor the end. It is, therefore, absolutely necessary to agree upon an initial moment or *Epoch* as it is called to measure time from. The time so measured has reference to the particular Era which begins at that Epoch. The Era is supposed to extend both in the past and the future without limit. Chronology treats therefore of the different Eras started by different nations at different Epochs. It furnishes the means with which one can fix or verify the dates of events mentioned in historical records with reference to particular Eras and can establish concordance among them.

2. Table I gives the details of about 25 Eras. But all of them are not in use at present. Most of them have shaded the fate of the nations that started them. Those Eras alone that have been thought fit to serve as basis of Astronomical Civil and Ecclesiastical calculation have survived. The Eras used at present in India in civil and religious transactions are (i) The Kali Yuga or the Yudhisthira Era (ii) The Vikrama Era (iii) The Shaka Era and (iv) the Christian Era. This last Era which

is the era of the present rulers of India and which is used throughout the civilized world has been chosen in Table I and elsewhere to serve as a thread of a string of beads connecting all the other Eras

3 The years are the chief constituents of the Eras. But they differ from each other in respect of their subdivisions or months. This difference introduces into Chronology the three systems of Calendars called the Luna-solar the Solar and the Lunar. The Shaka the Christian and the Mahomedan Eras follow respectively the above three systems

4 The years differ in other respects also such as the mode of enumeration their length and beginning. In some Eras the years denote the number of years completed or elapsed as in the Shaka and Kali yuga Eras. In others as in the A D or Christian Era they denote the current year. Again the years of the same system of Calendar begin with different months in different parts of India. The reader will do well to understand thoroughly the several details about each of the Eras given in Table I, and also to bear in mind their points of agreement and difference

5 **Mutual conversion of the years of different Eras**—By conversion is here meant the calculation of years of different Eras which begin in the same year of the Christian Era

There are three chief scales of numbering the years in Chronology. They are—

(1) The Mathematical scale of expired years—

$$-4 -3 -2 -1 \text{ E} + 0 + 1 + 2 + 3$$

(2) The Mathematical scale of current years—

$$-3 -2 -1 -0 \text{ E} + 1 + 2 + 3 + 4$$

(3) The Historical scale of mixed years—

$$\text{B C } -4 -3 -2 -1 \text{ E} + 1 + 2 + 3 + 4 \text{ A D}$$

The letter E indicates the year with which any Era adopting the scale, begins. In column 2 of Table I, is noted the scale which each Era follows.—Scales (1) and (2) are homogeneous but in Scale (3) the B C years are expired and A D years are current

On comparing the Scales (1) and (3) with (2) it is seen that—

- (a) The expired years can be changed into current ones by simply adding to the former $+ 1$ and for the converse by adding $- 1$
- (b) The historical years are changed into current ones of scale (2) by adding $+ 1$ to the B C years only, leaving the A D years untouched and for the converse by adding $- 1$ to the minus years of Scale (2)

The formula for the mutual conversion of years of different Eras is—

$$A + B - C = X$$

Where A is the given year of a given Era B is the Christian year in which the given Era begins as shown in col 2 of Table 1 C is the Christian year in which the required Era begins (col 2 Table 1) Then X will be the current year of the required Era

Before solving for X the given years A and the beginning years B and C must be changed into current years of Scale (2) by means of the above Rules (a) and (b) And after solution the current year X should be reduced, if necessary to its original Scale of expired years by adding $- 1$

Examples—Required (1) the Kali yuga (2) the Shaka (3) the Jewish and (4) the Julian period years corresponding to 1920 A D (5) the Kali yuga year corresponding to 40 B C (6) the Shaka and (7) Newar years corresponding to Kaliyuga 3000 and (8) the Christian year corresponding to Kaliyuga 3000

A	$B - C$	X	
(1) 1920 +	1 + 3101 = 3022	cur or 3021 exp	Kali
(2) 1920 +	1 - 78 = 1843	do 1842 do	Shaka
(3) 1920 +	1 + 3,60 = 3681	do Jewish	Era
(4) 1920 +	1 + 4712 = 6633	do Julian	Period
(5) - 44 +	1 + 3101 = 3056	do 3057 do	Kali
(6) 3001 - 3101 - 78 =	1822	do 1821 do	Shaka
(7) 3001 - 3101 - 879 =	1021	do 1020 do	Newar
(8) 3001 - 3101 - 1 =	-101	do 102 do	B C

Table 33 presents the view of the mighty river Time whose tributaries the Eras flow together without mixing and sweep before them all mortal things

CHAPTER II

ON THE NATURAL UNITS OF TIME AND THEIR USE

6 It appears that men derived their first ideas of time from observation of the most vivid and striking natural phenomena and that the interval between any two consecutive phenomena gave them the idea about the units of time. Sunrise is the most striking of all the natural phenomena and consequently, the interval between two consecutive sunrises came to be considered as the most important unit of time. Thus the smallest of the natural units is called *Day*. It is noteworthy that it also coincides with the cycle of bodily functions of animals such as work sleep digestion etc.

7 The next phenomenon that struck men in their nomadic life must have been the *Lunar phases*. They could easily watch from their huts the varying phases waxing from being a slender crescent till the Moon appeared round and full and then waning till she was reduced to a faint crescent and finally lost sight of in the rays of the Sun to appear again as a crescent on the Western horizon. This natural unit of time is called *Lunar month*. It consists of about 29½ days and its duration is long enough to suit the ordinary business of human life.

8 When hunting was found inadequate as a means of livelihood men must have been forced to betake themselves to agriculture. This change naturally drew their attention to the phenomena of *Seasons*. They observed that the Sun rose on the Eastern horizon at a particular point at the commencement or about the beginning of a particular season. After a long and patient course of observation they might have perceived that the cycle of the seasons exactly coincided with the cycle of the Solstices. This was a great discovery in that primitive state of

humanity. The cycle of seasons or the year, which consists of about 365 days, was the longest of the three natural units of time. The course of sacrifices, which was kept up by the Rishis and priests, throughout the year, seems to have been originally intended as a means of ascertaining the advance of seasons, so essential to agriculture. The Vedic hymns very aptly say that the seasons dwell in the year.

9 The knowledge of Astronomy among all the ancient nations of the world, such as the inhabitants of Egypt, Assyria, India and China, seems to be limited to the ascertaining of the lengths of these three natural units. The Vedic Calendar as we know it at present, from the Vedānga Jyotisha, is based on these three units only. The Eras were then unknown, or if they existed at all, they were the regnal eras, i. e., they began and ended with the reign of each king. In the Hindu Puranas, Chronology is often based on the lists of kings, but very rarely on the lengths of their reigns.

CHAPTER III

OBSERVATION OF THE MOVEMENTS OF THE SUN AND THE MOON AMONG THE STARS

10 Importance of Personal Observations.—To solve mechanically, the problems of Chronology by means of rules and tables, without understanding their theory, does not, in our opinion afford real pleasure. We therefore intend to render help in this direction, to any student, if he is only willing to bestir himself a little to acquire knowledge by personal efforts and experience. For this purpose, he should first select a place, from which he can see the whole of the circular horizon, unhindered by buildings, trees or hills, and commence his observations at dusk. He will then see that the stars are slowly and continually moving from east to west, that new stars are rising in the east and the old ones are setting in the west during the whole night. If he continues these observations for a few days, he will be convinced of the diurnal motion of the stars, the Moon, and the planets. But in the case of the Moon, he will notice this peculiarity, that in

addition to her motion westwards along with the stars she also moves eastward slowly among them. If he observes her positions relatively to stars for a month he will find that she has made one complete revolution in about $27\frac{1}{2}$ days and has returned to the star from which she had set out. The Stars Regulus (Vagha) Spica (Chitrâ) or Antares (Jyestha) may conveniently be used as starting points in making this experiment (Fig 1)

11. The Sun also moves like the Moon among the stars from west to east and completes one revolution in about $365\frac{1}{4}$ days. But as the Sun and the stars cannot be seen side by side like the Moon owing to his overpowering lustre it is not easy to determine the exact period of his revolution among the stars without the aid of instruments. A rough estimate of it can be obtained by observing the mean duration of the *heliacal* risings and settings of one of the bright stars like Canopus or Agastya which phenomena are given in a Panchanga every year.

12. The Sun's motion can only be inferred. The Moon appears to rise or set on the horizon of a place almost diametrically opposite to the Sun on the Full Moon day. This cannot happen unless both the luminaries travel nearly along the same route over the sky. The route is called the *Zodiac* and the great circle which runs along the middle of it is called the *Ecliptic* or the place where the eclipses happen. The observer's work will be much facilitated if he makes use of a star atlas* in his observations.

13. The Earth considered as Motionless.—The ancient astronomers with the exception of the Indian Astronomer Aryabhatta believed that the Earth remained fixed† in the centre of the Universe and that the Moon and the Sun revolved round her in $27\frac{1}{2}$ and $365\frac{1}{4}$ days respectively. This belief continued to prevail till about the year 1500 A.D. when Copernicus declared that the Earth rotated round its axis and at the same time revolved round the Sun with the Moon revolving round her. We shall

* The author's Marathi Vakshata Vijnana contains 5 celestial maps and much useful information about the stars.

† Compare the words *Loka*, *terra* and Sanskrit *Sthira* meaning the Earth the *terra firma*.

however stick to the old belief, in explaining the ideas about the *tithis*, and *nakshatras*, as the appearances from the earth's surface easily lead to it. Their explanation we shall attempt in the next chapter.

14. The reader will have noticed that the chief drawback in the natural units of time is their *incommensurability* with each other (see Table 37, *Days and Months*). Not one of them is an exact multiple or a sub-multiple of any other. Men were therefore required to keep the account of time in these three units separately. The annual register, in which this account is kept, is called a *Calendar* or a *Panchāṅga*. The *Calendars* are called Lunar, Solar, and Luni Solar, according to the importance given to one or the other or both of these units.

15. The Zodiacal section of the starry vault (Fig. 1) over the head of a person on the equator may be considered as the dial of a vast clock, over which the Sun and Moon revolve like the hour and minute hands. In the *Lunar Calendar*, the time is measured by the number of conjunctions of the Sun and the Moon hands on this dial, and 12 of these conjunctions, or *lunations* as they are called, are supposed to make one year. In the *Solar Calendar*, the existence of the Moon-hand is wholly ignored, and the years are reckoned by the number of revolutions of the Sun-hand alone with reference to a fixed point or a star such as the Star Spica. The year is sub-divided into 12 months each containing a certain number of days fixed arbitrarily or upon some principle.

16. The *Luni Solar Calendar* is a complex thing and is rather difficult to comprehend. In it the months are lunar, and the years are solar. The inconvenience caused by the incommensurability is remedied, however, by means of the intercalary months, which are peculiar to the Luni Solar Calendar. The *tithis* mark the position of the Moon in relation to that of the Sun, while the *nakshatras* denote her position in relation to a fixed starting-point. The *Yogas* are simply the sum of the distances of the Sun and the Moon from the starting point, and as such they do not indicate any natural phenomenon.

CHAPTER IV

THE SKY-DIAL AND THE CLOCK-DIAL COMPARED

(Figure 1)

17. In the preceding chapters we have described how the Sun and the Moon appear to revolve continually along the same path among the stars, and how the periods of their revolutions were utilized by the ancient people to measure their time, which is the chief object of Chronology.

But with our eye placed on the surface of the earth, it is impossible to see the whole of their path at one view and consequently the description fails to be as clear and impressive as it ought to be. We shall therefore, change our stand-point and describe their motions as they would appear to us from a most distant point perpendicular to the plane of their orbits.

18. *View from an Imaginary Stand-point.*—When seen from the surface of the Earth, only half the Ecliptic is visible above the horizon at any instant, and the other half is hidden under it. In order to bring the whole of the Sun's orbit in our view, we must recede far away from the Earth, and place ourselves in empty space. We know from daily experience, that objects begin to look smaller as we recede from them. We may, therefore, imagine to have travelled millions and millions of miles towards the *southern side* of the Ecliptic to a place whence the entire orbit of the Sun may look as small as the dial of a clock, and the Earth a mere point at its centre. We may also imagine for the sake of analogy that the Sun and the Moon revolve in the same circle with their own angular motions and that they are connected with the common centre *E* of their orbits with bars so as to present, in accordance with the Siddhantic or Ptolemaic system, the appearance of the hour and minute hands respectively. As we now no longer partake of the Earth's diurnal rotatory motion, we may imagine that we see the Sun's orbit, i.e., the ecliptic, with the stars set on its rim, quite at rest, as shown in Fig. 1 and the Earth's southern hemisphere rotating clock-wise in 24 hours. Although a point, the Earth is here magnified so

as to show Africa, Australia and South America, India being out of view

19. View of the Ecliptic superposed by a Clock Dial.—

Next suppose that the Ecliptic is superposed by a clock dial, so that the 12 o'clock point coincides with the zero starting point of Ashvini and the 6 o'clock point coincides with the brilliant Star Spica when seen from E, the Earth's centre. In this position the hour divisions of the dial will coincide with the 12 equal divisions or Rishis of the Ecliptic, and each minute-space on the dial will contain six degrees of longitude on the Ecliptic. Consider another circle, concentric with the dial, to be drawn outside the dial and to be divided into 27 equal parts from the same zero starting point of Ashvini, representing the 27 nakshatra spaces. Also imagine that a smaller moveable card board circle ABC has its diameter KEA firmly attached to the Sun-hand EAS by two clamps, so that it is always carried by the Sun hand along with it like the *alarm wheel* in a clock. Suppose the circumference of this smaller moveable circle to be divided into 30 equal parts, representing the tithis, beginning from the point A.

20. Illustration.—Figure 1 will present a lucid and impressive picture of the daily movements of the Sun and the Moon in the sky, affording correct and vivid ideas of the tithi, the nakshatra, and the yôga, as understood in a Luni Solar Calendar from analogy we shall now call the hour and minute hands (ES, EM) on the dial, the Sun and Moon hands respectively. Now suppose that the Sun and the Moon hands occupy in the sky the positions of the hour and minute hands respectively, when the time by the clock is 36 minutes past four o'clock. In this position the *Sun hand* will be at the 23rd minute space, and consequently its longitude from the origin O of Ashvini will be equal to $23 \times 6^\circ = 138$ degrees on the dial. The Sun hand shall have also brought with it the ending point A of the 30th tithi or Amāvāsya, pointing to 138° degrees. Similarly, the *Moon hand* being at the end of the 36th minute-space its longitude from the origin O will be $36 \times 6 = 216$ degrees, which are marked along the edge of the Zodiac.

21. The Tithi—The angular distance *SUM* of the Moon from the Sun is called the *Elongation* of which 12 degrees make one tithi. In the present instance $216^{\circ} - 138^{\circ} = 78^{\circ}$ is the Elongation. This divided by 12 gives the number of *tithis* elapsed to be 6½. Also the Moon hand *TM* supports this calculation by crossing the tithi-circle exactly in the middle of the 7th tithi.

22 The Nakshatra—The longitude of the Moon is 216° . This divided by $13\frac{1}{2}^{\circ}$ (the length of a Nakshatra space) gives 16.2 as quotient. This means that the Moon hand has travelled over 16 nakshatras and has finished a fifth part of the 17th nakshatra which is called *Anuradha*. (See Appendix.) The Moon appears to occupy this very position on the circumference of the outer circle in Fig. 1. The nakshatra occupied by the Sun is for distinction called the *Mahanakshatra*.

23 The Yoga—The nakshatra of the Sun hand is here similarly found out by dividing the Sun's longitude 138° by $13\frac{1}{2}$. The quotient is 10.35 which indicates that the Sun is moving in the 11th nakshatra called *Purno Phalgun*. This is borne out by its position in Fig. 1 where it will be seen to have crossed a third of the 11th nakshatra. The sum of the nakshatras of the Moon and the Sun is called a *Yoga* which literally means a Sum. It is merely a numerical expression and does not indicate any phenomenon. In this instance the Yoga is $16.20 + 10.35 = 26.55$ i.e. the 27th Yoga *Vardhanti* is current.

24 The Mahapata—When the sum of the tropical longitudes of the Sun and the Moon (i.e. longitudes measured from the vernal Equinox) amount to 180° or 360° there is the possibility of the moon being at the same point in time called *mahapata* which is to be attended by special Hindu religious ceremonies. In the former case it is called *Vyatipata* and in the latter case *Vardhanti*. In the *Vyatipata* the two luminaries when possible attain equal declinations on the same side of the celestial equator while in the *Vardhanti* they possibly do the same but on the opposite sides of it.

Note—The problem of finding the exact moment when the centres of the Sun and Moon attain the same declination was considered in ancient times. The spherical trigonometry was unknown as the most crucial test of a astronomer's proficiency.

26. *Karanas*.—The halves of tithis are called *karanas*, so that there are 60 *karanas*, in a lunar month. They resemble the half hourly strokes in a clock.

26. The Solar and the Lunar Solar months and dates.—The sun-hand in its annual course beginning with the zero point of Ashvini marks the Solar month and date on the dial. In Figure 1 it is in the sign *Sinha* and has finished three-fifths of it. The Solar date is, therefore, approximately the $\frac{30 \times 3}{5} = 18$ th of *Sinha* or *Cingam* of Malabar (Table 15)

As the Moon hand *EM* walks 13 times faster it overtakes the Sun hand in each of her monthly revolutions. The instant when the two hands are seen one over the other, is the ending moment of *Amāvāsyā* (Sanskrit — *Amā* = together and *Vasā* = to dwell), or conjunction. It is also the last moment of the preceding Lunar month and the beginning of the next. In the present case (Fig. 1) the Moon hand indicates the 7th tithi, and the Sun hand the 18th solar date. So twelve days after, the Sun hand will enter the sign of *Kanyā*, and the *Kanyā Sankrānti* will therefore occur on the $7 + 12 = 19$ th tithi or *Vadi-chaturthi*. Hence the current lunar month is *Bhādrapada* (vide secs. 66 and 70) and the tithi is *Shukla Septamī*.

The *Pakshas*—After the *Amāvāsyā* or conjunction, the phases of the Moon go on increasing till she comes to *R*, which point is moving with the Sun diametrically opposite to it. There she appears full and round, and the aspect is called *Purnimā* or Full Moon. The period from *Amāvāsyā* to *Purnimā* is called *Shukla-paksha* or bright fortnight and that from *Purnimā* to *Amāvāsyā* is called *Kṛishṇa paksha* or dark fortnight.

27. The perpetual Clock.—By practice one is enabled to state the number of the current tithi by a mere glance at the Moon's orb. The chief bright star in the nakshatra, which rises at about sunset opposite to the Sun, tells approximately the name of the Lunar month. It also shows the progress of the night by its altitude at any moment. Thus the ancient Hindus had turned the starry vault into a big eternal clock. It required no winding nor was the motion of the hands affected by atmospheric changes. It was a real *Swayam vaka*, i. e., keyless kalayantra.

28 The points of difference between the artificial and Heavenly Clocks—We will now notice the points of difference. In the former the motions of the hands are uniform and commensurate : ϵ they are related by simple ratios. In consequence of this interdependence the configurations of the tithis nakshatras and yogas recur not only at fixed intervals but at fixed points on the dial. But these two essential properties being absent in the motions of the Sun and the Moon the conjunctions oppositions and quadratures do take place at any time and at any point of the dial of the celestial clock. It often happens that at the moment when the Sun hand reaches the zero point of Ashvini at the end of the Solar year the Moon hand is seen anywhere on the celestial dial. For instance (see Table 3) in the Kali year 0 the Sun arrived at the zero of Ashvini on the Celestial Clock Dial on 3 579 (Tuesday 34gh 44 pa.) when the tithi was 27 795 ϵ the Moon was on $(27\ 795 \times 2) = 55\ 6$ minute spaces distant from the Sun.

The absence of interdependence is therefore the reason why it is necessary to compute separately the positions of the Sun and the Moon on the heavenly dial and thence to calculate the moments of the completion of the tithis nakshatras and yogas and to publish them in a panchanga in advance for the observance of the religious rites and the performance of civil transactions.

The nature and cause of the variable motions will be explained in the next chapter and the method of computation of the Lunar Solar Calendar will be described in Chapter IV.

CHAPTER V

MEAN AND TRUE POSITIONS

The variable Daily Motions of the Moon and the Sun (Fig. 2)

29 The ancient astronomers believed that the Sun the Moon and the planets revolved with uniform motion in perfectly circular orbits and that although the Earth's centre was the centre of the Ecliptic or Zodiac yet the centres of their orbits were placed not in the Earth's centre but at some distance from it. That owing

If Of be the direction of the Moon f with respect to the line CA , pointing to a star at infinite distance, when seen from O at a certain moment, then Ef or its parallel Cr will be her direction with respect to the same star-line CA , if seen from E , the Earth's centre.

32. It is manifest then that in the first half of her mean anomaly from 0 to 180 degrees, she (r) always appears behind her mean position f , and is always ahead of it in the second half, i.e., from 180 to 360 degrees. (Vide Table 32.) Also although the motion round the centre C is always uniform viz. $791'$ she will appear to move with continually accelerated motion and enlarging disc in the first half of her anomaly, owing to the continuous decrease in her distance fE from the Earth E . Similarly her motion will appear continually retarded in the second half owing to the increase in her distance fE every moment the minimum and maximum being $722'$ and $839'$ (Vide Table 25)*.

Considering the conditions of the problem it is obvious that the Equation of the Centre must reach its maximum (302') where Of is perpendicular to AP . Put in Table 72 we find the maximum given when Of is perpendicular to AP i.e. when the mean anomaly is 90 or 270 degrees. This is no doubt wrong. The error may be traced in the infancy of Astronomy when it was guessed for the first time that the equation or inequality increased with the sine of the anomaly and not in arithmetical progression as was supposed in the time of the *Phāṇaśā*. The correct calculation required the knowledge of Trigonometry which being then unknown the primitive astronomers were content with the Tables 11 and 12 of the equation calculated with the sine of anomaly only and called it sine-correction *सिक्खर* *Śikṣar* *Śikṣar* alludes to this defect but is unable to explain it. He simply calls it a strange theory and asks his pupils not to raise the question why the annual parallax is not similarly computed with the sine of the commutation angle.

नादृशमन न नर विविधं यतो विविधा कल्पमनादयः

सूत्रनिर्वाणाय ॥ ३० ॥

What is said above in respect of the Moon's movement applies wholly to the Sun's movement also.

* Note.—The error is explained all the inequalities by means of syzygies and even trace on the hypothesis of secular orbits and variation of distance. So we have done the same here. For all the theories see authors *Merrill* & *Crabtree*.

33. Effects of the Equations of the Centres of the Moon and the Sun, on the ending moments of tithis, nakshatras and yogas—It is easy to see that when the Moon is behind her mean place she will be late in arriving at the required distance to make up the required tithi nakshatra and yoga. Therefore the correction to the mean ending moment due to the equation of the Moon's centre, must be plus or additive in the first half of her anomaly. See Tables 7, 8 and 10. Similarly, owing to the advance of the Moon beyond her mean position during the next half she arrives sooner at the required distance, and the correction must, therefore be minus or subtractive so far as the Moon is concerned.

34 The lagging of the Sun behind its mean position increases the elongation and his advance diminishes it. So that a given tithi takes place earlier and the correction must therefore be minus in the first half of his anomaly and plus in the next half, so far as the Sun is concerned. See Table 6.

The effect of the Sun's equation of centre on the ending moment of a yoga, is similar to that of the Moon on the ending moment of a tithi. See Table 9 (*Plus* in the first half and *minus* in the second half of the Sun's anomaly.)

The Sun can produce no effect on the ending moment of a nakshatra which depends entirely on the Moon's equation of the centre.

35 The suppression* and repetition or Vridddhi of tithis etc., how caused—The equations of the centres of the Sun and the Moon by causing variations of the ending moments of the tithis nakshatras and yogas, also shorten and lengthen their durations. The duration of a tithi varies between 54 0 gh. and 65 3 gh. that of a nakshatra between 54 0 gh. and 66 3 gh. and that of a yoga between 52 2 gh. and 61 5 gh. When the duration of a tithi exceeds 60 gh. it sometimes happens that the tithi begins shortly before the Sunrise on one day continues during the 60 ghs

* Of course kshaya tithis would occur even if the motions of the Sun and Moon were uniform as a mean tithi of 59 gh. is smaller than a natural day of 60 gh. but in that case they would occur at uniform intervals as in the Vedic calendar and there would be no tithi vridddhi. The inequalities in the motions render the intervals between kshaya tithis irregular and make tithi vridddhi possible.

of it, and ends shortly after the Sunrise of the following day. As the tithi on which the Sun rises is supposed to rule over that day the same tithi is shown on the two consecutive days in the Panchanga. This is called *The tithi Vriddhi* or the *Trisparsha* tithi. On the contrary, when the duration is less than 60 gh., it occasionally occurs that a tithi begins shortly after the Sun rise of a day, and ends shortly before the next Sunrise. In this case the tithi touches neither the preceding nor the following Sunrise, and is looked upon as a *kshaya tithi* or expunged tithi, and is not shown in the Panchanga. The Vriddhi and Kshaya of nakshatras and yogas occur under similar conditions. The yoga is more liable to be suppressed than repeated.

36 The difference between the mean and true motions of the Moon is greatest at *A* and *P* and nil at *B* and *D* i.e. it varies as the cosine of the anomaly. The equation of the centre, which is the integral or the total sum of all the differences of motion varies therefore as the sine of the anomaly according to the principle of Calculus. (Table No. 38)

CHAPTER VI

THE IDENTITY OF THE ANCIENT AND MODERN INEQUALITIES OF THE SUN AND THE MOON

37 The ancient Assyrian astronomer were undoubtedly the most intelligent and keen sighted people. The absence of accurate instruments for measuring time and angles in those ages probably compelled them to limit their observations to eclipses only. It is really wonderful that under such difficulties they should have succeeded so much in their determination of the solar and lunar inequalities. Their coefficients are of course the aggregate of the coefficients of the modern inequalities as they appear on the occasion of the eclipses.

38 We shall now demonstrate how the chief modern inequalities of the Moon and the Sun can be combined into two groups, one depending on the solar and the other on the lunar anomaly.

The following are the principal inequalities adopted by Prof. P. Hansen in his lunar and solar theories —

The inequalities of the Moon

Equation of centre	— 377 4 sin $\{ \epsilon \text{ s anomaly} \}$
Evection	— 74 4 sin $\{ (\epsilon - O) - \epsilon \text{ s anomaly} \}$
Variation	+ 35 7 sin $2 (\epsilon - O)$
Annual Variation	+ 11 9 sin $O \text{ s anomaly}$
Parallactic Equation	— 2 6 sin $2 (\epsilon - O) - O \text{ s anomaly}$

The inequality of the Sun

Equation of centre	— 115 3 sin $O \text{ s anomaly}$
--------------------	-----------------------------------

39 At the time of the eclipses the terms of the form $2 (\epsilon - O)$ in the above arguments become zero. Consequently the third lunar inequality called variation vanishes altogether. The fourth and the fifth inequalities can be grouped with the Sun's inequality with their signs changed in order that they may not adversely affect the time of the eclipses by the transfer.

The fifth inequality twice undergoes the change of sign first owing to its transfer and secondly owing to the sign (—) minus attached to the Sun's anomaly in it and therefore remains unchanged.

Consequently on the occasion of an eclipse the following two groups can be formed out of the six inequalities

The Lunar Group

$$\begin{cases} - 377 \cdot 4 \sin \epsilon \text{ s anomaly} \\ + 71 \cdot 4 \sin \epsilon \text{ s anomaly} \end{cases}$$

The Solar group

$$\begin{cases} - 115 \cdot 3 \sin O \text{ s anomaly} \\ - 11 \cdot 9 \sin O \text{ s anomaly} \\ - 2 \cdot 6 \sin O \text{ s anomaly} \end{cases}$$

40 By summing up these groups separately we obtain the following two single inequalities representing in value all the chief modern inequalities

$$\epsilon \text{ s equation} = - 303 \cdot 0 \sin \epsilon \text{ s anomaly}$$

$$O \text{ s equation} = - 129 \cdot 8 \sin O \text{ s anomaly}$$

These are identical with the following two inequalities, determined from observation by the Assyrians twenty five centuries ago (See Table 37 under *Surya Siddhanta*)

$$\begin{aligned}\epsilon \text{ s equation} &= -302' 4'' \text{ in } \epsilon \text{ 's anomaly} \\ \odot \text{ s equation} &= -130' 5'' \text{ in } \odot \text{ s anomaly} \\ &= -432' 9''\end{aligned}$$

Note—The author of this work believes that the above demonstration is entirely his own and that he has not been anticipated before.

CHAPTER VII

DEFINITIONS OF TECHNICAL TERMS

(Figure 3)

The information and explanation given in the foregoing chapters may have it is hoped prepared the student's mind to understand the definitions of the following terms which are *technical*. Many of them will appear mere recapitulations of what has been explained before.

TERMS SIGNIFYING SPACE

41 The *Siddhantic* or *Ptolemaic System*. Ancient astronomers supposed that the Earth lay at rest in the centre of the Universe and that the planets moved round it in circles in the following order:—the Moon, Mercury, Venus, the Sun, Mars, Jupiter and Saturn. The planets farther than Saturn moved far beyond the orbit of Saturn. Their motion was uniform and was due to a great whirlwind called *Pravahanti*.

42 The apparent path of the Sun among the stars is called the *Ecliptic* (Fig. 1, p. 3). It is supposed to be divided into 360 degrees, each degree being subdivided into 60 minutes and each minute being again subdivided into 60 seconds. The Moon and the planets always appear to move near it.

43 The initial point on the Ecliptic from which the circular distances or longitudes of the Sun, the Moon and the stars are measured is called the *first point of Aśvini* or *Aśvinī*. It is situated according to the old *Surya Siddhanta* quoted in the

Pancha Siddhāntikā, diametrically opposite to the bright star Chitra (Spica, Fig 1) But owing to an excess of about 3 minutes in the period of the sidereal year adopted in all the Siddhantas this 1st point shifts itself forward, at the slow rate of about one degree in 420 years [Pāṇ. sec 200 (a) and sec 152 (c)]

44 The 12 equal parts into which the Ecliptic is divided, beginning at the first point of Ashvini are called *Rāshis* or signs. The entry of the Sun into a Rashi is called his *Sankramana* or *Sankranti* (Fig 1), which is often used as a synonym for Rāshi

45 The 27 equal parts into which the Ecliptic is divided, beginning from the first point of Ashvini, are called the *Nakshatras*. Generally, the most conspicuous star found in the space of each Nakshatra is called its *Yōgārd* (Fig 1)

46 The distance of a heavenly body, measured eastward from the first point of Ashvini to the foot of the perpendicular dropped from the body upon the ecliptic is called its *longitude*, and the perpendicular is called its *latitude* (Fig 3) P_n is the Moon's longitude and nm her latitude

47 The angular distance of the centre of the Moon from the centre of the Sun is called her *elongation*. Twelve degrees of elongation make one *tithi space* so that there are 30 tithi spaces in the circle of elongation, which is denoted by the symbol ($\epsilon - \odot$). (See Figs 1 and 3)

48 The linear distance from the centre of the Earth to the centre of the orbit of the Moon, or to the centre of the supposed orbit of the Sun is called the *eccentricity*. It produces the equation of the centre (See the line EC in Fig 2)

49 The point on the circumference of the Moon's orbit, which is farthest from the Earth, is called the *Apogee* and the nearest point is called the *Perigee* (Fig 2)

50 The angular distance of the Moon or the Sun from their respective Apogees, as seen from the centre of their circular orbits, is called the *mean anomaly* for instance, the angles AOF in Fig 2 But as seen from the Earth's centre E , it is called the *eccentric* or *true anomaly* as the angles AEF

51 *The equation of the centre* is the angular distance, by which the Sun or the Moon moving uniformly in the eccentric orbit, is seen behind or ahead of the mean position. It vanishes at Apogee and Perigee and attains its greatest value nearly half way between those two points. See the angles EfC or the arcs fr (Fig. 2)

52 *The Celestial Equator* is a great circle equidistant from the two poles. It cuts the ecliptic in two opposite points called the *equinoxes*. The point through which the Ecliptic passes to the northern side of the equator is called the *Vernal Equinox* and the other point is called the *Autumnal Equinox* (Fig. 3). The equinoxes have a slow retrograde motion of $50'' \cdot 2$ per year.

53 The distance in degrees reckoned on the ecliptic from the vernal equinox to the foot of the perpendicular dropped on the ecliptic from a celestial body is called its *tropical longitude*. In Fig. 1 the angle $\angle ES$ (160°) and in fig. 3 the arc OS are the Sun's tropical longitude.

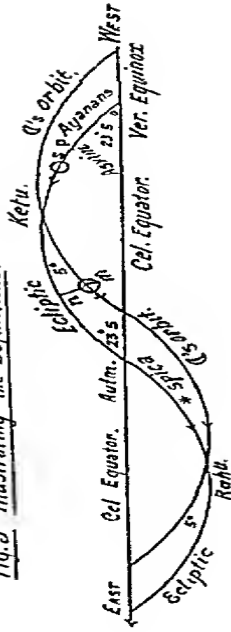
54 The tropical longitude of the first point of Ashvini reckoned in degrees is called *Ayanámshas*. The *Ayanámshas* according to Manu increase slowly at the rate of about $59'$ per year of which about $8'' \cdot 5$ are due to the annual shifting eastward of the first point of Ashvini (P) owing to the excess of the sidereal year of Surya's and $50'' \cdot 2$ due to the actual precession of the Vernal Equinox (Q). (Fig. 3)

55 The orbit of the Moon cuts the ecliptic in two opposite points called *nodes*. The node through which the orbit passes to the northern side of the ecliptic is called *Rahu* and the other is called *Ketu*. These nodes have a daily retrograde motion of about $3'$ (Fig. 3).

56 The longitude of that point of the Ecliptic which is in contact with the horizon of a place at a given moment is called the *Lagna* at that moment.

57 The independent variable often expressed in angle or time on which depends the value of a dependent variable is called an *Argument*. It is always stated at the head of each table and is shown on one or two sides of it.

Fig. 3 Illustrating the Definitions.



A table has sometimes two arguments and is then called a table of *double entry* as the Tables 12, 28, 35, 36. One of them is shown on the vertical side and the other on the horizontal side of the table. In this case the quantity to be found out lies at their crossing point.

58. The angular correction made to the mean value in order to obtain the true one is called an *equation* or an *inequality* as the angle E/C (Fig. 2).

TERMS SIGNIFYING TIME

59. The instant when the true Sun arrives at the initial point of Ashvin P (Fig. 3), is called the *Meshaṣṭī* or Epoch of the commencement of the Hindu sidereal year (Table 3).

60. The time in which the Sun departing from any fixed star returns to the same star is called the *sidereal year*. According to the *Sūrya Siddhanta* its length is 365 258 750 484 days. But according to Prof. Newcomb it is 365 256 898 4 days.

One-twelfth of a sidereal year is a mean solar month, and the time taken by the true Sun in passing through a given Rāṣi is the true solar month corresponding to that Rāṣi. (Vide Section 70.)

61. The time that passes between two conjunctions of the Sun and the Moon is called a *lunation* or a *lunar month*. Its mean duration is 29 530 587 946 days. One thirtieth of a lunar month is a mean tithi or lunar day, and its length is 98435 of a day.

62. The period in which the Moon makes one complete revolution with reference to any fixed star is called a *sidereal month*. Its length is 27 321 674 160 days.

63. The time of the Moon's revolution from apogee to apogee is called an *anomalistic month*. Its length is 27 554 590 9 days.

64. The time reckoned in ghatis from the apparent sunrise at a place is called *Savana*. It is employed in the performance of the Hindu religious ceremonies.

Note—1 day = 60 ghatis, 1 ghati = 60 palas, 1 hour = 2 5 ghatis, 1 minute = 2 5 palas and 1 pala = 0 4 of a minute.

CHAPTER VIII

THE THEORY OF THE ADHIKA AND KSHAYA MONTHS

(For practical determination *vide* sec. 108.)

65 The *adhika* or the intercalary month is a peculiarity of the Luni-solar calendar and is due to the excess of the solar year over the lunar by 11 0648 tithis. This excess amounts to one lunar month in 32 332 solar months or 7 lunar months in about 19 solar years.

The luni-solar calendar is the most ancient and has been in use among the Chaldeans the Hindus the Jews and the Chinese. The intercalary months were assigned by them to certain fixed years of their cycles (*vide* secs. 129 151 154) and being calculated with mean motions there was no possibility of a *Kshaya* month.

It were the Hindus it appears who first took the bold step of introducing into their calculations the true motions and positions of the Sun and the Moon. But this step opened a doorway for the strange and hitherto unknown *Kshaya* month i.e. the suppressed month.

66 Lunar months how named.—That lunar month in which the Sun enters the Mesha Rashi is called Chaitra; that in which he enters the Vrishabha Rashi is called Vaishakha and so on. The lunar month in which no Sankramana occurs is called *adhika* and bears the same name as that of the next lunar month. That lunar month in which two Sankramanas occur gets two names,* of which the first is retained and the second is suppressed or joined to the preceding.

67 Importance of the Adhika months.—Table 2 furnishes all the Adhika and Kshaya months that have occurred or shall occur from Shaka year 0 to 2105. In calculating the ending moment of a given tithi it is absolutely necessary to know beforehand whether the given year contains any Adhika or Kshaya month. For without this knowledge it is impossible to determine the exact number of tithis intervening between the epoch of the Mesha Sankranti and the given tithi. (*Vide* sec. 79.)

* The author has seen at Hoshiar a manuscript copy of an old panchāṅg containing a *Kshaya* month. It contained a month having two names joined together as Vārgashalā Pancha.

68 Prescience of the Adhika months—When the elements for the epoch of *Vesha Sankranti* are calculated (sec 77) the *tithi* or the *Tithi Shuddhi** as it is called by way of pre-eminence can tell us whether the year contains an Adhika month and if so what month is most likely to become Adhika. * An Adhika month is possible only if the *tithi Shuddhi* is between 19 and 31 and is impossible outside these limits. For instance the *Tithi Shuddhi* for *Kali* year 0 in Table 3 is 27 79. This *Tithi Shuddhi* lying between the said limits the year 0 contained an Adhika month which was most probably *Jyestha* as the next section shows.

69 The limits of the Adhika and Kshaya months—The following are the limiting values of *tithi-shuddhi* within which each of the months shown against them may possibly become Adhika or Kshaya.

Note—The limits are common to *Surya Arya* and *Brahma Siddhantas* alike.

Limits of Tithi Shuddhi

Between—29 6—31 2	Adhika Chaitra is possible
28 2—30 4	Vaishakha
26 4—29 1	Jyestha
24 5—27 3	Ashadha
22 4—25 3	Shravana
20 8—23 3	Bhadrapada
19 8—21 7	Ashvina
19 3—20 6	Kartika
19 3—20 1	Marga Shirsha or Kshaya Kartika
19 4—20 1	Marga Shirsha,
19 5—20 2	Pausa
19 3—20 7	Adika Phalguna

Note 2—The limits of the months *Kartika*, *Marga Shirsha* and *Pausa* are nearly equal and as such are of little practical value. It is only after actual calculations of the times of the *Sankrantis* and new Moons that we are able to decide which of them is Adhika or Kshaya.

* The week-day of the *Vesha Sankranti* is usually called *Adhaya* i.e. the lord of the year.

70 A solar month is often called by the name of the Rashi, in which the Sun is moving and its length is the time which he takes to cross the Rashi. In the following table are given the names of the lunar month, and the names of the solar months, connected with them in the manner stated in the first sentence of section 66 and also the lengths of the solar months in days according to the *Sūrya-siddhānta* :—

Name of Lunar month	Connected Solar month	Length of Solar month in days	Name of Lunar month	Connected Solar month	Length of Solar month in days
Chaitra	Mesha	30 01	Ashvina	Tula	29 89
Vaishakha	Vrisha	31 42	Kartika	Vrischika	29 49
Jyēṣṭha	Mithuna	31 64	Marga	Dhanu	29 32
Ashadha	Karka	31 48	Pausa	Makara	29 45
Shravana	Sinha	31 02	Magha	Kumbha	29 82
Bhādra	Kanya	30 44	Phālguna	Mina	30 35

Note—The lengths of the solar months remain invariable for centuries but those of the Lunar months vary between 29 27 and 29 82 days.

71 *Apptitude of months for becoming Adhika and Kshaya*—A lunar month can become Adhika if the duration of the solar month connected with its preceding month is greater than that of a lunar month and it can become Kshaya if the duration of the solar month connected with itself is less. See the preceding section.

The 7 months from Phālguna to Ashvina fulfil the first condition only and can on that account become always Adhika but can never become Kshaya. The Kartika and Margashirsha months fulfil both the conditions in respect of the limits (29 27 — 29 82 days) of a lunar month but within a very small margin. They therefore can become both Adhika and Kshaya but rarely.

The month Pausa has almost no chance of becoming Adhika but has a greater chance of becoming Kshaya than the month Margashirsha. The month Magha can become Adhika but not Kshaya. But the limits are so narrow that it has never become either Adhika or Kshaya.

72 The limits of a Kshaya month are so narrow and so nearly identical with those of an Adhika that it is generally preceded and followed though not immediately by an Adhika month, so that there are often two Adhika months when a Kshaya month occurs. The shortest period of its recurrence is 19 years in which the change in the tithi shuddhi is only 0.231, but that in the Moon's anomaly is $-50^{\circ} 3'$. The other periods of recurrence are 46, 65, 122 and 141 years made up of multiples of 19 plus 8.

Ganesh Dattajna gives in a verse the following Shaka years which contain a Kshaya month according to the Surya Siddhanta: 1482, 1603, 1744, 1895, 2026, 2045, 2148, 2167, 2232, 2373, 2392, 2514, 2533, 2653, 2674, 2796 and 2815. He also gives additional Shaka years which contain a Kshaya month when calculated by the Arya Siddhanta. They are 1481, 1763, 1901, 2129, 2186 and 2251.

CHAPTER IX

THE LUNI-SOLAR CALENDAR

According to the Surya Siddhanta

73 This calendar has been in use in India from the earliest time down to the present. In its present form probably since Shaka 200 it uses the true positions of the Sun and the Moon instead of the mean ones as in *Vedanga Jyotisha*. Though this was a real advance in the right direction yet it has necessitated troublesome calculations. The solar calendar is much simpler to calculate and seems therefore to have been adhered to by our brethren the Bengalees and the South Indians.

74 The Sankalpa.—Before proceeding with any religious ceremony a pious Brahman must declare solemnly his intention to perform it according to the formula called Sankalpa. The Sankalpa opens with the recital of the chronological order of the grand divisions and subdivisions of time beginning with the *Shra Shreta Vardha Kalpa* down to the very tithi, nakshatra, yoga and karana of the day as well as of the geographical position of the place and of the signs occupied by Jupiter and other planets.

A Panchāṅga is therefore as much necessary to his religious life as

food and water are to his worldly existence. It is this inseparable connection of Astronomy with the Hindu religion that has saved the former from total neglect.

75 The three chief Siddhantas and the parts of India where they are used—A comprehensive standard work on the theory and practice of Astronomy is called a *Siddhanta*. There are three such works: the *Surya S°*, the *Arya S°* and the *Brahma S°*. The first is used throughout the Indian Peninsula on account of its greater accuracy. The second is used in Malabar, Travancore and the Tond Districts of Madras while the third is followed in Gujerath and parts of Rajputana but is at present being gradually abandoned in favour of the first.

76. The Karanas or Manuals—In the *Siddhantas* the calculations are made from the Epoch of Mahayuga or of the Kalyuga, and consequently it is almost impossible to compute a Panchanga directly from any of them. Rudimentary tracts called the *Karanas* (not to be confounded with the half of a tithi) based on these *Siddhantas* have consequently sprung up from time to time, and have been given up in favour of new and better ones. At present the *Karanas* of *Surya S°* which have been extensively used in Upper India and Bengal are the *Maharand* and the *Ramarand*. The *Grahalaṅkāra* of Ganesha which is far superior to them is used in Central India and the Deccan. Those of the *Arya S°* are the *Pañjikā*, the *Karana pralasha* and the *Lakṣita*. These are followed in Malabar and South India. The *Karana kutūhala* of Bhaskara follows the *Brahma S°*.

TO CALCULATE THE ENDING MOMENT OF A TITHI IN UJJAIN MEANTIME (U. M. T.)

77 Method—When the given year is of the Shaka Era, add 78 to it and the sum will indicate the A. D. year. With the century of the A. D. era as argument enter Table 3 and take down the elements for that century. Below them write their increase for odd years given in Table 4 and add up the elements separately. The sums will represent the values of the elements at the commencement of the given solar year which is the same as the Moment of Mesh Sankranti otherwise called *Meshadi*.

78 Complete the fractional tithi by adding to it its complement in decimal fraction. Diminish the complement of the tithi by one sixty fourth part of itself and call the remainder C.

Write the value of C below the elements of Vara date and the Sun's anomaly and put zero below those of Rahu and Avanamsha when they are required (*vide* sections 162 169 175).

Multiply C by 13 and place the product below the element of the Moon's anomaly as degrees.

Add up all the elements separately and denote them by S. This part of the working is called the *completion of the Tithi Shuddhi* whereby we obtain the values of the elements at the ending moment of the tithi Shuddhi.

79 Refer the Shaka year to Table 2 and see if it contains any Adhika or Ishaya month. Then count the number of tithis elapsed from the beginning of the Luni Solar year (which begins on the first tithi of Chaitra) to the end of the given tithi taking into account the 30 tithis of the Adhika month and omitting the 30 tithis of the Ishaya month if there be any, and denote the total by T.

Deduct from T the completed tithi shuddhi S, and call the remaining tithis R. Thus $T - S = R$ and $S + R = T$.

Enter Table 5 with R as argument write the increments below the elements denoted by S and add them separately. The sums will be the mean elements at the ending moment of the given mean tithi T.

80 To obtain the ending instant of the true Tithi as seen from the Earth's centre, and the English date corresponding to it.

Enter Table 6 with Sun's anomaly as its argument take out the Sun's equation of centre expressed as fraction of a day, and place it below the Vara and English date.

Multiply the Sun's equation by 12 (more correctly by 12.2), put the product as degrees below the Moon's anomaly and add them up.

With this corrected anomaly of the Moon, enter Table 7, take out the Moon's equation of centre, and place it below Vāra and date.

Add up the three quantities according to their signs. The integers of Vāra indicate the number of the *Week day*: one indicating Sunday, two indicating Monday, and so on.

Multiply the fraction of the Vāra by 60, and the integers of the product will denote the *ghatis*. Multiply again the fraction of *ghatis* by 60, and the product will represent the number of *palas*.

Thus we arrive at the *Vāra ghatis and palas*, of the time when the tithi ends.

81 *To determine the English month and date*—All that one has to do now is to refer to Table 11 and find out the highest number of days that can be subtracted from the total of days, calculated in the column headed *A D date* and to subtract them. The remainder will show the month and date of the Christian Era, the year being shown in the third column of the working. (*Vide* Sec 82, type of calculation) The year should be increased by unity when the date passes December 31.

Note 1—The English date is here supposed to begin at mean sunrise of Ujjain

On referring to Table 2 we see that in 1831 the month Shravana was adhika. Counting this adhika, which precedes Mâgha we obtain 11 for the number of months elapsed since the beginning of the Luni Solar year 1831. Consequently the required tithi is the $(11 \times 30) + 18 = 348$ th from the beginning. —This is denoted by T in the following working.—

TYPE OF CALCULATION

Tithi—Mâgha Krishna 3 of Shaka 1831

Explanation.	Shak year	A D year	Tithi	Vara	A D date	ζ s an m	\odot s anom
Tab 3	1832	1900	13 027	5 670	1 12 620	7° 30	280° 80
4	8	8	28 518	3 070	0 070	16 30	0 00
4	1	1	11 065	1 259	0 259	9° 09	0 00
At Meshadi.	1831	1909	22 610	2 949	1 12 949	116 38	280 60
Complement			390	0 384	0 384	4 90	38
S the completed tithi			23	3 333	13 333	121 38	280 98
Tab 5 Arg R 320			300	7 306	295 306	259 20	291 00
			20	5 687	19 687	257 20	10 40
			5	4 922	4 922	64 30	4 80
T, the desired mesh tithi			348	1 248	333 248	341 08	236 18
Tab 6 Sun's Eq: Arg 236° 2				+ 149	+ 0 149	+ 1 78	+ 149x12
Tab 7 Moon's Eqn Arg 342° 9				- 133	- 0 133	34° 46	= + 1 78
End of the desired true tithi T				1 264	333 264		
Tab 11 April 0 to Feb 0					706		
Engl date A D 1810 Feb Sunday					27 264 = 10 gh		50 palas
The same by D B Feb 1					27 264 = 10 gh		50 palas

EXPLANATION

83 The computation upto the elements of the desired mean tithi T is too easy to require explanation. We then enter Table 6 with Sun's anomaly $236^{\circ} 18'$ as its Argument and take out the Sun's equation $+ 149$ day and write it below the Vara and date.

We then multiply the Sun's equation $+ 0 149$ by 12 and add the product $+ 1^{\circ} 78'$ to the Moon's anomaly $341^{\circ} 08'$ and obtain $342^{\circ} 86'$. With this value of Moon's anomaly we enter Table 7 and obtain $- 0 133$ day for the Moon's equation of the centre,

and we write it below that of the Sun in the columns of Vara and date. Lastly we add up the three quantities according to their signs and get Vara 1 264 is the *ending moment* of the required tithi.

The integer 1 in the Vara indicates that the tithi ended on a Sunday. The fraction 0 264 multiplied by 60 yields 15 84 ghatis and the fraction 0 84 multiplied by 60 yields 50 palas. So the result is that the tithi *Magha Krishna 3 of Shaka year 1831 ended on a Sunday at 15 gh and 50 pala after the mean Sunrise at Ujjain*. Fractions of a day are easily converted into ghatis and palas by means of Table 40.

This result is in complete agreement with that obtained by D. B. Pillai in his *Chronology*, page 15.

84 The English date — In the column for date we have A 333 days. By referring to Table 11 under April we see that the highest number that can be subtracted from 333 is 306 upto the end of January or February 0. This being subtracted we get 27th of February 1910 because the year 1909 ended on December 31 and the year 1910 commenced on January 1.

Note — The method of converting the meantime of Ujjain into the time reckoned from the true Sunrise of any place is explained in Chapter XVI.

CALCULATION OF THE ENDING MOMENT OF A NAKSHATRA

85 Connected with a month and Tithi — A nakshatra or a yoga unless connected with any lunar month has no significance at all. We shall therefore explain here how to calculate the ending moment of a nakshatra concurrent with a given tithi, at mean sunrise. (Cf. Section 116.)

86 Definition — A tithi counted from the preceding New Moon of a current month is a *monthly tithi* while the same counted from the beginning of Chaitra is called an *annual tithi*. In the present example 18 is the monthly tithi and 348 is the annual tithi.

Note — Here the words tithi and yoga should be understood to mean the spaces indicated by them and not the times.

87. *Method*.—Put the monthly tithi and the Sun's anomaly into their places in the following formula, and solve it for the nakshatra. The nakshatra thus derived will be running at the moment indicated by the Vāra of the mean tithi T.

$$\frac{3}{40} \{ (12^\circ \times \text{monthly tithi}) + \odot\text{'s anom} + 77^\circ 26' \} = \text{Nal}$$

Then in place of the annual tithi T, in the preceding calculation, put the fractional nakshatra, and retain only the Moon's anomaly, omitting the Sun's anomaly as unnecessary.

Complete the fractional nakshatra by adding to it its decimal complement. Increase this decimal complement by one eightieth part of itself and then add it to Vāra.

Multiply the increased complement by 13 and add the product to the Moon's anomaly as degrees.

With the Moon's anomaly take out from Table 8 the Moon's equation for Nakshatra and add it to the Vāra.

The result will be the *ending moment* of the completed nakshatra from the mean Sunrise of Ujjain.

88. *Example*.—Find the ending moment of the nakshatra current with Māgha Krishna Tithi 18 of Shaka year 1831.

Putting the monthly tithi 18 and the Sun's anomaly $236^\circ 18'$ into the preceding formula and solving it for nakshatra, we get 12.708 as mean nakshatra current with the 18th tithi. The fraction .708 belongs to the 13th nakshatra which is named Hastā (See the Appendix.)

CALCULATION OF THE ENDING MOMENT OF A YOGA

89 Method—It is similar to that of a nakshatra. Calculate the current mean *yōga* by the following formula employing in it the mean nakshatra, obtained by the formula of Section 88

$$2 \times \text{nakshatras} - 0.9 \times \text{monthly tithis} = \text{yoga}$$

Put this *yoga* in place of the *tithi* as before. Complete it by adding to it its decimal complement. Diminish the complement by one seventeenth (17th) part of itself and add it to *Vara* and to the Sun's anomaly. Multiply the diminished complement by 13 and add the product in degrees to the Moon's anomaly.

Then with the Sun's anomaly take out from Table 9 the Sun's equation of centre and write it under the *Vara*.

Multiply the Sun's equation by 14 and add the product in degrees to the Moon's anomaly with the Moon's anomaly thus corrected take out from Table 10 the Moon's equation and write it below that of the Sun. Then add up the *Vara* and the two equations according to their signs.

The result will be the ending moment of the completed *yoga* from the mean Sunrise of *Līlān*.

90 Example—Find the ending moment of the *yoga* occurring at mean Sunrise with *Vaḥa* *Kṛishna* 3 of *Shaka* year 1831.

First we calculate the current *yoga* by the above formula of Section 89 and get for it 9.216 the fraction .216 belongs to the *yoga* *Gardā*. (I see the Appendix)

$$(2 \times 12.708) - (9 \times 16) = 9.216 \text{ } yogas$$

Type of calculation of a Yoga

Explanation	<i>Yoga</i>	<i>Vara</i>	<i>Equation</i>	<i>Obtained</i>
<i>Yoga</i> current at T	9.216	1.248	341° 08'	9.46.18
Complement	94	738	8.89	74
Ganda <i>Yoga</i>	10.44	1.986	350.67	238.97
Tab 9 Arg 237° Sun's equation	—	0.67	—0.85	—(61 × 14)
Tab 10 Arg 9.0° Moon's equation	—	0.67	349.87	—0.87
Ganda <i>Yoga</i> ends Sunday		1.8.8	—51.67	29.10.18

Take this round number for R and calculate, as before the ending moment of the resulting tithi, $S + R = T$

Should the tithi T thus found, end on either the preceding or the following date, the number of the tithi should be corrected so as to tally with the given date.

For instance suppose that it is required to calculate the tithi which concurs with the Sunrise of the English date, Sunday, the 27th of February 1910

In the example of Section 82 the completed tithi shuddha S is 23 and the date is April 13.333 We know from Table II that the period from April 0 to 27th February is $306 + 27 = 333$ days

Subtracting 13.333 days from 333 days we get 319.667 days Dividing these by 63 we get 5.074 as quotient Adding 319.667 and 5.074 we get 324.741 or in round number 325 tithis, which represent R in this instance

With this R we proceed as in the example of Section 82, and arrive at the result that $23 + 325 = 348 = T$ which was Māgha Krishna 3 of Shaka year 1831 as Shrāvana was adhika in 1831 by Table 2

THE MOST ANCIENT TITHI MENTIONING THE WEEK-DAY

94. **Example 2.**—Calculate the ending moment of Ashāḍha Shukla dwadashi, Thursday, in kalyuga year 3585 or Shaka year 406

This is the celebrated test problem selected by Mr Dixit and others in their works on Chronology. The date appears on a pillar erected by the king Budha Gupta at *Fran* (Lat 24° N Long 78° 15' East from Greenwich) in the Central Provinces. It is the oldest inscription that mentions the week-day along with the tithi

We conclude from Table 2, that Shaka year 406 contained no adluk month, and, therefore, the tithi was 102nd from the beginning of the Shaka year 406. Also the tithi-shuddhi 5·222 in the working, supports the conclusion. (*Vide* Section 68)

Ashādha Shukla 12 of Shaka year 406.

Explanation	Shaka year	A D year	Tithi	Vāra	A D. date	anom	☉'s anom
Tab 3	322	400	8 777	0 486	M. 17-486	104° 20'	280° 6'
" 4	84	84	29·445	0 735	0 735	175 93	0 0
At Meshādi ..	406	484	5 222	1·221	M. 18 221	280·13	280·6
Complement ..	..	..	·776	·776	·776	9 96	·8
h. completed tithi ..	..	..	·6	1·987	18·987	290·09	281·4
Tab 5 Arg R. 9d ..	..	..	9d	4·592	88·592	77·50	87·3
			6	5·906	5·906	77·20	5·8
T. Ashādha 12 ..	..	..	102	5·485	113·485	84·79	14·6
Tab 6, Arg 14·5, ☉'s eqn ..	..	..	..	—·046	—·046	—·55	—·016
Tab. 7, Arg 84·24 ☉'s eqn. ..	..	..	..	+·414	+·414	84·24	× 12
End of Ashādha 12 ..	..	..	..	5·853	113·853	= 51 gh	11 pa
Tab. 11, March 6. to June 6	..	..	..	..	92°		
Engl. date A.D. 484 June	..	..	..	Thurs	21·853		
By D. B. Pillai, Chron. age 92	..	..	..	..	21·853	= 51 gh.	11 pa

The above calculation shows that Ashādha Shukla 12, Shaka year 406, ended on a Thursday at 51 gh. and 11 palas, and that the English date on that day was June 21 A.D. 484.

The week-day, Thursday, confirms the truth and genuineness of the Inscription.

95 We shall now calculate the *nakshatra* and *yoga* of this memorable date according to Sections 87—91.

By Sections 87 and 89—

$$\begin{aligned} & \downarrow \{ (12 \times 12) + 14 \cdot 5 + 77 \cdot 26 \} = 17 \cdot 682 \text{ Nakshatra.} \\ & \quad \{ (2 \times 17 \cdot 682) - (0 \cdot 9 \times 12) \} = 21 \cdot 584 \text{ Yoga.} \end{aligned}$$

Calculation of the Nakshatra on Ashādha 12, Shaka 406

Explanation	Nakshatra	Vāra	Q. s. anom.
At the end of 10 th nīti the Complement	17 68° 318	5 485 319	34° 79 4 16
The Nak. falls on Fr day By Sec 91 and Table 18	18 —1	5 804 —1 012	88 98 —13 22
Anurādhā	17	4 792	75 73
Tab 8 Arg 75° 73 Q. s. eqn		+ 377	
End of Anurādhā at By D B Pillai Chro page 12	10 gh 8 p 10 gh 1° p	5 169 5 170	Thursday

96 Next let us calculate the yoga

Calculation of the Yoga on Ashādha 12 Shaka 406

Explanation	Yoga	Vāra	Q. s. anom.	Q. s. anom.
At the end of 10 th nīti the Complement	4 570° 435	5 485 319	84 9 7 76	14 5° 4
Yoga ends next day Sec 91 Table 18	75 —1	5 804 —1 012	90 0 1° 31	14 8 — 0
Shukla Yoga	4	4 419	27 75	14 0
Tab 9 Arg 14° 0 s. q		+ 18	+ 56	= { + 040 × 14
Tab 10 Arg 78 Q. s. eqn		555	8 31	
Shukla ends Thursday By D B Pillai Chro page 1*		5 44	27 Ch	31 pa
		5 443	3 cl	24 pa

97 Calculation of the Christian date on which Buddha died B C 483, Kartika Shukla 8.—The date appears in an article by Dr Fleet in the Journal of the Royal Asiatic Society for 1909. We shall work out this problem as an illustration of the method of calculating a tithi occurring in B C years, which be beyond the limits of Table 2.

In the working of this example below, the tithi Shuddhi, i.e., the tithi at Meshādī is 26 6. It falls within the limits of possibility of adhika Jyestha (*vide* Section 69) which precedes Kārtika. The number of months elapsed since Chātrādī is therefore, 8 and the tithi in question is 248th.

In Table 3 the year B. C. 483 lies between B. C. 501 and B. C. 461 and commences 18 years after B. C. 501.

Note—B. C. years are to be considered as minus. They succeed in the descending order.

Calculation of the Christian date of Buddha's death

Kārtika Shukla 8 Shaka — 560 October 13, B. C. 483 Tuesday

Explanation	Shaka year	B. C. year	Tithi	Vāra	B. C. date	C. s. / an. m.	O. s. / an. m.
Tab 1	—578	—501	7 427	1 605	1 9 605	10° 23'	250° 6'
4	16	16	27 637	6 140	0 140	33 51	0 0
4	2	2	22 130	2 517	0 517	184 16	0 0
At Meshādī	—500	—483	26 594	3 262	1 10 262	236 91	260 6
Complement			406	400	400	5 20	0 4
S. completed tithi			27	3 662	10 662	242 13	261 0
			200	0 671	196 671	52 10	194 0
Tab 5 R. 221			20	5 687	19 687	257 20	19 4
			1	0 984	0 984	12 87	1 0
T. Kārtika Sh. 8			248	4 204	228 204	204 33	145 4
Tab 6 Arg 135° 4'			— 127	— 127	— 127	— 1 51	— 127
Tab 7 Arg 202 8			— 149	— 149	202 80		× 12 =
Kārtika Sh. 8 ends			3 923	227 923			— 1 53
Tab 11 Mar 0 to Oct 0				214 000			
Date B. C. 483 Oct 13 Tuesday				13 974	55 gh		41 pa
By D. H. Pillar Oct 13 Tuesday				13 920	55 gh		12 pa

28 In the above example we have assumed, on the strength of Section 69, that Jyestha was adhika in B. C. 483. We shall now show from actual calculation that our assumption was a fact.

We take down the following elements for the Meshadi of B C 483 from the preceding working

Calculation of Adhika Jyestha in B C 483

Explanation	B C year	Tithi	Vāra	Q s anom	O s anom
At Meshadi	483	26 594	3 46*	235° 33'	280° 6'
Tab 13 increase for Mithuna		63 347	6 356	94 60	61 5
Mithuna S begins		80 941	2 618	331 53	342 1
Complement		0 099	658	0 70	0 1
3rd New Moon		80	2 678	33° 28'	342 2
Tab 6 Arg 342° 2' O s Eqn			+ 056	+ 0 67	+ 056
Tab 7 Arg 33° 28' Q s Eqn			- 004	33° 28'	x 12
Time of 3rd New Moon			2 578		= + 67

It is quite obvious from the above figures that the Mithuna (3rd) Sankranti occurred at 2 618 and that the third New Moon (Amanta) fell on the same day at 2 528 i.e. (2 618 — 2 528) = 0 09 day or 5 4 ghatis before the beginning of Mithuna.

Deducting 0 09 day from the period of the Vrishabha Sankranti (vide Table 13) which is 31 42 days we get 31 33 days which exceeds the duration of the longest lunar month 29 81 (See Note to Section 70). Consequently no Sankranti did occur between the 2nd and the 3rd New Moon and the month Jyestha was undoubtedly adhika in B C 483.

99 Problem—To calculate the English date on which the Sun attains a given tropical longitude.

Example—Required the English date of the Summer Solstice in B C 483 on which the Buddhist holiday of Vassa was held.

The Summer Solstice occurs at the moment when the Sun's tropical longitude is exactly 90°. But our Hindu year being sidereal we have been all along working with the sidereal longitudes without ever feeling the need for tropical longitudes. So we must have now some link for connecting the sidereal and tropical longitudes. This is furnished by the precession of the

Vernal equinox called the *Ayanamshas*. In other words the *Ayanamshas* are the tropical longitude of the first point of *Ashvini* (Section 54)

Table 3 contains the *Ayanamshas*. They are meant to be applied to the sidereal longitudes for converting them into the tropical ones. But in the above example we have to do the opposite. They must therefore be applied to the tropical longitudes with their sign changed to get the sidereal ones.

From Tables 3 and 4 we obtain $-16^{\circ} 48'$ of precession or *Ayanamshas* for B C 483. These applied with the sign changed to 90° give $106^{\circ} 48'$ for the Sun's sidereal longitude at the moment of the Summer Solstice in B C 483.

The problem then comes to this—To find the English date in B C 483 on which the Sun's true sidereal longitude was $106^{\circ} 48'$ —This is solved in the following manner, remembering that the mean longitude (sidereal) of the Sun at the moment of *Mesha Sankranti* is always $357^{\circ} 86'$ owing to his apogee being considered fixed. (See Secs 190 and 192.)

Date of Summer Solstice in B C 483

Explanation	B C year	☉'s longitude (°)	☉'s anom	Date (9)	Ths Tab 18
				days	
At <i>Mesha'di</i> Example Sec 97	483	357 9	280 0	M 10 26	26 0
Table 3 Col (8) (9) motion		100 0	100 0	101 50	103 0
Do do do		8 0	8 0	8 10	8 1
Do do do		0 6	0 6	0 60	0 6
Mean longitude		106 5	29 "	120 46	138 3
Table 31 Arg $29^{\circ} 2'$ ☉'s eqn -1° changed to			+1 0		
Do $30^{\circ} 2'$ ☉'s eqn $-1 1$			30 "	+1 10	0 0
Total days from March 0				121 56	138 3
Table 11 days from March 0 to June 0				97 00	170 0
Date of the Solstice B C 483 June				Old Style	29 56 18 3
By D B P's calculation Chro page 5					29 59 Sec 152c

The reason of adding the Sun's equation of centre to the anomaly with its sign changed is to account for the change in the Sun's equation which influences the time of the Sun's attaining the required true longitude.

Note—In the Old Style the Solstices recede on the dates as the years advance. To stop the recess is the main object of the New Style, which has since its adoption fixed 21st June as the day of the Summer Solstice. Before the reformation in the Calendar of Julius Cæsar it was 25th June.

100 The later *Sūrya Siddhanta* has been the *Almagest* of India for the last 15 centuries and has been acknowledged as authority in matters astronomical. Almost all the subsequent works on astronomy have been more or less based on it and it is much venerated in India as being a direct revelation from the Sun (*Vide Sec 207*). As all the past civil and religious transactions have been guided by the *Panchangas* conforming to it it is absolutely necessary for the Epigraphist to use them as searchlight in his difficult work of verifying and fixing the dates of ancient events.

But it will be unnecessary to allude to it in future when the great discovery of the new observations and the refined methods of calculation of modern European astronomers are available to us. We must venerate and admire it as an ancient relic testifying to the high degree of excellence attained by the ancients under very adverse circumstances. [*Vide Chap. XVII, Note 1 to (d)*].

Already *Panchangas* based on the Nautical Almanac have gained considerable popularity among the educated men for their perfect agreement with the easily observable phenomena such as the eclipses and conjunctions of planets. But however accurate the calculations of the Nautical Almanac may be it would be unwise to remain permanently dependent on it as it is in itself

an annual publication. We must have our own works on astronomy, prepared in the light of modern researches and discoveries.

The last Indian Astronomer worthy of the name was *Ganesh Dairajna* who wrote his famous *Grahalāghata* in the year A D 1520, i.e., exactly four centuries ago. He has united in his book both accuracy and ease, the most desirable qualifications of a *Karana* to such a degree that no one has since been able to surpass him. He has well maintained the respectable position conferred on him by posterity.

But unfortunately he lived in an age long before the dawn of modern Astronomy. The Copernican Solar System, Kepler's laws, Newton's law of gravitation, the invention of the telescope, the theory of perturbations developed by Lagrange and Laplace, the lunar theory perfected by Hansen, Delaunay and Newcomb, the discovery of the new planet Neptune from the perturbations of Uranus by Leverrier and Adams, these are the triumphs of Modern Astronomy which were not even dreamt of in his time.

The present author thinks that it would not be considered out of place to mention here, that he has done his best to fill up the gap of these four centuries by securing for his countrymen, the benefit of the later Western discoveries. He has composed in A D 1898 works in Sanskrit called *Jyotirganitam*, *Ketaki* and *Vasjayanti*, in which he has based his calculations on the elements and constants determined by Leverrier, Hansen and Newcomb. But almost all the tables in his *Jyotirganitam* had to be reconstructed so as to suit the Hindu method of calculation. He has composed 7 other works in Sanskrit and Marathi on such subjects as the problem of two bodies, the theory of elliptic motion, the path of the Moon's penumbra on the surface of the Earth, the star atlas and the like. The example of a table worked out in the next Section will, it is hoped, testify to the accuracy accomplished in his *Jyotirganitam*.

101. Problem —To calculate the ending moment of a tithi from the corrected elements of *Sūrya Siddhānta* so as to agree, within a few palas with that obtained directly from the *Nautical Almanac*

Method —Calculate the mean ending moment of the given tithi *T* according to Sections 77 78 and 79

Add to the elements of *Vara* the English date and the Moon's anomaly the following constants of correction, viz. $+ 0.014$, $+ 0.014$ and $+ 3^{\circ} 33'$ respectively. These constants will serve for the next one or two centuries. The Sun's anomaly requires no correction whatever.

102 Then as before enter Table 6 with the Sun's anomaly, take out the Sun's equation, and write it below the *Vara* and the date of the mean tithi *T*.

Multiply the Sun's equation by 12 and add the product in degrees to the Moon's anomaly. Deduct from this corrected anomaly of the Moon the product of the monthly tithi by twelve viz. $12^{\circ} \times$ monthly tithi (see the definition in Section 85) and the remainder will be the vertical argument of Table 12. The monthly tithi itself should be taken for its horizontal argument.

Table 12 is an instance of double entry. When the monthly tithi lies at the top we should enter the Table with the vertical argument commencing at the left hand top-corner and take out the Moon's equation with the left hand sign attached to it. But when the monthly tithi lies at the bottom we should enter it at the right hand bottom corner and take out the equation with the right hand sign attached to it as is done in the next example.

103 Example —We will calculate the ending moment of *Nya Shuklaṅga* *Brishma* *Shastha* 6 of *Shaka* year 1831. The difference between the ancient and modern tithis is greatest about the 9th and 21st monthly tithis for a given Sun's position from the Moon's apogee. Here the monthly tithi is the 21st.

Type of Calculation

Explanation	Shaka year	A D year	Tithi	Vāra	A D date	☾ s anom	☾ s anom
Tab 3	1822	1809	13 027	5 670	12 670	7 39	780° 6
4	8	8	23 518	3 070	3 070	16 76	0 0
4	1	1	11 005	1 259	0 259	9° 09	0 0
At Meshādi Complement	1831	1809	22 610	2 948	12 949	116 25	280 6
			390	384	384	4 99	4
S. Completed tithi			23	3 333	13 333	1° 21	781 0
			160	0 435	98 435	206 10	97 0
Tab 5 Arg R 148			40	4 374	39 374	154 40	38 6
			8	0 875	7 875	10° 80	7 8
T mean tithi Shrā 21			121	2 017	159 017	221 64	64 6
Correction Sec 101				+ 014	+ 014	- 3 33	0 0
Jyotirgan ta Shrā 21			121	2 031	159 031	22° 9	64 6
Tab 6 Arg 64° 6 ☾ s Eqn				- 161	- 161	- 1 93	- 0 161
						226 04	× 12
21 × 12° = 25 ☾ - ☉						- 25° 00	- 1 93
Tab 12 Arg 334° ☾ s Eqn				- 495	- 495	334 04	
True tithi ends				1 375	158 375		
Tab 11 April 0 to Sept 0				days	153		
Sept 5 Sunday True tith ends at					5 375 = 2 gh	30 pa	
By N Almanac					5 367 = 2 gh	n pa	
By D B Pillai					5 403 = 4 gh	1° pa	

Note —The reader will note that the method of Jyotirganita is direct and not hampered by successive approximations

The ending moment of the tithi comes to 22 gh and 2 pa when worked out with the data of Nautical Almanac using the method of Interpolation

Our Table 12 is taken from our Jyotirganitam. It is formed by the combination of the Variation Erection the equation of centre of the Moon and a few minor inequalities depending upon the combinations of the different multiples of the Moon's anomaly and elongation

104 Karanas —The Karanas (Section 25) are the halves of the tithis. So there are 60 Karanas in a Lunar month. Their number is made up by the repetition of the 7 Karanas eight times

in a lunar month beginning with the second half of the Shukla pratipada which is called *Bara* and ending with the first half of the Krishna Chaturdashi which is called *Bhadra* or *Isti*. The remaining four *karanas* are immovable. See the Appendix.

Their calculation—The ending times of the *karanas* which are assigned to the second halves of each *tithi* coincide with those of the *tithis* themselves and therefore there is no need for their calculation. The ending times of the first halves or *karanas* of *tithis* are got by adding the *Vari ghatis* and *palas* of two consecutive *tithis* successively and dividing the sums by two.

In a Panchanga the ending time of that *karan* alone is shown which is current at sunrise.

CALCULATION OF TITHIS

According to the Arya and Brahma Siddhantas

(Special Tables 14 and 16 to be used)

105 These two Siddhantas have been in use only since the beginning of the 4th century of the Shaka Era. As their constants are almost identical with those of the Surya Siddhanta (vide Table 37), it is not considered advisable to prepare all the foregoing tables for each of them except the table of elements for the century. We have therefore prepared Tables 14 and 16 to be substituted for Table 3 of the Surya Siddhanta in the calculation of the *tithis*. Table 15 and 17 to be substituted for Table 13 in the calculation of *Sakrantis* according to the Arya and Brahma Siddhantas respectively. All six of the Tables 14-19 are to be used as before.

The Siddhanta Shukra-nakṣatra-kārikā has we believe never been used as a table of Panchangas. It occupies the highest place among theoretical works and is often quoted as authority on points of theory only. Its *Karana-kautūhala* has been thrown into back ground by the *Grahalaḥvara* of Ganesha. So it is of little use to prepare tables based on the constants of Shukra-nakṣatra-kārikā. Brahmagupta was an admirer and follower of Brahmagupta.

106 As a model we shall calculate below, the ending moment of the famous *tithi* Ashādha-Sukla 12, of Shaka year 406 or A.D. 494 by making use of the elements of the two Siddhantas.

According to the Arya Siddhānta

Ashādha Shukla 12 Shaka 406.

Tables	Shaka	A D	Tith	Vara	A D March	☾ s anom	☉ s anom
	Year	Year		Days	Days	Degrees	Degrees
14	400	500	9 283	0 361	18 361	309 13	°80 0
4	—16	—16	—27 032	—6 140	—0 140	—33 51	0 0
At Meshad Complement	416	484	9 246 754	1 221 749	18 221 749	275 6 9 63	°80 0 0 7
	S		6	1 963	18 9 3	°85 2	°80
5	R		90	4 592	88 592	77 50	87 3
			6	5 906	5 906	70	5 6
	T		109	5 461	113 461	79 97	13 8
6 Arg	14° 9 0 s eqn			043	—0 043	—0 52	{ — 043
7 Arg	79 5 ☾ s eqn			+ 412	+ 412	74 45	{ ×12=
40	Thurs 49 gh 48 pa			5 830	113 830	June 1	—0 57
See infra							

According to the Brahma Siddhānta

Ashādha Shukla 1st Shaka 406

Tables	Shaka	A D	Tith	Vara	A D March	☾ s anom	☉ s anom
	Year	Year		Days	Days	Degrees	Degrees
16	400	500	1 35	6 361	17 461	296 67	°80 6
4	—16	—16	—27 03	—6 140	—140	—33 51	0 0
At Meshad Complement	406	484	4 320 640	0 321 6 0	17 321 6 0	283 11 8 71	°80 6 7
	S		5	0 991	17 991	271 87	281 3
5	R		90	4 599	88 599	77 50	8 3
			7	6 890	6 890	90 06	6 8
	T		10	5 473	113 473	9 32	15 4
6 Arg	15° 4 ☉ s eqn			— 04	— 04	— 36	{ — 047
7 Arg	78° 4 ☾ s eqn			+ 411	+ 411	8 6	{ ×12=
40	Tues 50 gh 13 pa			5 837	113 837	June 1	— 56
11	March 0 to June 0 days				9		

Note—The ending times calculated by Diwan Bahadur L. D Swami Kannu Pillai are exactly the same as the above ones

107 The Ekadashi Fast—The Mādhvas and Vaishnavas in the Karnataka are strictly enjoined by their Spiritual Gurus to follow the Ārya Siddhanta in the observance of the fortnightly Fast of Ekadashi. This partiality for the Ārya Siddhanta is probably due to the fact that both Aryabhata and Śrī Madhvacharya were natives of Malayalam.

But the elements of the Ārya Siddhanta not being accurate enough (compare Tables 3 and 14) the Ārya Siddhanta Tithi ends at present (A.D. 1920) 3 gh 50 pa later than the Surya Siddhanta Tithi. For this reason the Surya Siddhanta Panchangas have been in general use throughout the Karnataka and the Ārya Siddhanta Panchanga is nowhere followed except at Udupi which is the Holy place of Madhvaism in South Canara.

The day being supposed to begin with the 50th ghati for religious purposes there is the possibility of the Ārya Siddhanta Ekadashi being contaminated by the touch of the Dashami when the Surya Siddhanta Dashami ends at about 52 ghatis. This is the occasion for the most scrupulous care in the calculation of the ending moments of the three tithis beginning with the Dashami exclusively with the Ārya Siddhanta elements. This is generally done with the help of the Karasaparakasha. But in obedience to the precept of Vidyadhara Munī the Rekhanāra correction must be omitted in the calculation of the Savana Time.

Example—We shall calculate Pausa Krishna 12 of Shaka year 1841 for the latitude of Bijapur $\approx 17^\circ$ North. This was the occasion of a protracted *i.e.* Atinikta Ekadashi when the fast lasted 2 days & produced a general agitation among the Mādhvas.

Pausa Krishna 12 Shaka year 1841

Explanation	Shaka	Tithi	Vāra	☾ s anom	☉ s anom
Tab 14 Ārya	182°	19 805	5 514	7° 73	280° 00
4	16	27 037	6 140	33 51	0 00
4	3	3 194	3 776	76 28	0 00
At Meshād Complement	1841	13 046 914	1 430 900	317 52 11 70	290 00 0 90
5	R	14	2 330	3° 9 22	280 00
Tab 5		900	0 871	52 11	194 03
		80	1 748	308 84	77 61
		3	2 953	38 58	2 91
T Pausa	vads 12	99	0 909	8 70	195 45
Tab 6 Arg	185° 4	☉ s equ	+ 048	+ 0 58	+ 048
Tab 7 Arg	9° 3	☾ s equ	+ 075	9 33	$\times 12 = 58$
The tithi ends (U M T)		Sunday	1 0°	≈ 1 gh	30 pa

We must now calculate the corrections to be applied to the above meantime to reduce it to the duration from Bijapur Sunrise by Section 182. The equinoctial shadow for 17° is 3.7 by Table 34.

We first calculate the Sun's tropical longitude by Section 173.

Sun's anomaly in the above example	195° 45
apogee	77 26
equation	0 05
The precession Tabs. 3.4	22 83
Tropical longitude of Sun	<hr/> 295 59
Then we obtain from Table 33—	gh p
Arg 195° 45 Bhujāntar	—0 5
Arg 295 59 gives —18 33pa —18 33 × 3.7 shadow	
= Chara	—1 6
Meantime of ending moment	<hr/> 1 30
Time from Bijapur Sunrise	<hr/> 0 19

The result shows that Dwadashi ending 19 palas after the Sunrise the Ekadashi was *Atirakid* so that the fast had to be observed for two days.

CHAPTER X

THE SOLAR CALENDAR

Sankrantis, Adhika and Kshaya Months, and Solar dates
(According to the *Surya Siddhanta*)

108 The Sankrantie—When the tithi Shuddhi and the Vāra specially called *Āditya* at the moment of Vesi-ādi for any given year is obtained by Section 77 the mean tithi and Vāra of the remaining Sankrantis are obtained by adding to them the increase upto the beginning of each Sankranti given in Table 13. This is exemplified in the calculation of the Adhika months.

Adhika Months—Calculate the elements for the Veshādi of the given year by Section 77. Refer the tithi Shuddhi to Section 69 and find out the probable Adhika month.

Refer the probable adhika month to Section 70 and find out the preceding and the connected Sankrantis of the probable adhika month

Write the elements of Meshādi in two places and add to them separately as given in Table 13 the increments upto the beginning of the preceding and current Sankrantis

Then calculate by Sections 78 79 80 the ending moment of the nearest Amanta & the New Moon using Table 5 and negative complement where necessary

Thus you get the ending moments of two consecutive Sankrantis and Amantas

Write these four results in the order of their occurrence. If the Amantas lie between the Sankrantis then the assumed month is adhika *de facto*. If not the preceding or the following month should be treated as above

In the determination of a Kshaya month a series of consecutive Amantas and Sankrantis beginning with Kartika, must be calculated and arranged in the order of their occurrence, before it is possible to determine the Adhika and Kshaya months by the Definitions of Section 68

Fortunately the Kshaya months are of very rare occurrence

Example—Calculate the Adhika Shravana of Shaka year 1831 See Ex Sec 82 We must calculate the Karka and Simha Sankrantis here

Time of Karka Sankranti and 4th Amanta

Explanat n	Shaka	Till	Vala	Q s anom	Q s nom
At Meshādi	1831	2° 630	2 949	116 49	280 60
Tab 13 Karka mot os		9° 494	3 000	148 10	02 30
Karka Sankrant Time of Complement		118 1° 4 8° 6	5 949 86°	204 49 11 40	13 50 86
Tal > R		119 1	6 011 084	275 09 1° 86	14 38 0 97
Tab 6 Arg 13 3 Q equation Tab 7 198 5 Q s equation		120	6 995 — 64 — 403	234 03	15 33
Time of 4th Amanta			6 545		

* The correct number for tithi is 22 610 See example of Section 82

Time of Sinha Sankrānti and 5th Amānta.

Explanation	Shaka	Tithi	Vāra	C's anom.	O's anom.
At Mesbādi	1831	22·630	2·949	116·39	230·60
Tab 13, Sinha.. ..	..	127·470	6·476	199·30	123·70
Sinha Sankrānti, time of .. ..	..	150·100 —·100	2·425 —·100	315·69 —1·30	44·30 —10
		150	2·325	314·39	44·20
Tab 6, Arg 44, O's equation .. ..	..	..	—·136		
Tab 7, Arg 314, C's equation .. ..	..	..	—·316		
Time of 5th Amānta . . . . .	..	..	1·874		

ORDER OF OCCURRENCE

Karka Sankrānti ..	Thursday	.. 5·949	Āhādha.
4th Amānta ..	Friday	.. 6·545	Adhika
5th Amānta ..	Sunday	.. 1·874	Shrāvana.
Sinha Sankrānti ..	Monday	.. 2·425	Nija Shrāvana

Note.—The Shrāvana is adhika, there being no Sankrānti between the 4th and 5th Amāntas.

The Solar Calendar

109 *Explanation*—The present Indian solar calendar is in principle the same as the Christian calendar, both depending on the period of the Sun's revolution, which is sidereal in the former and tropical in the latter.

The duration of a month in the former is the time which the Sun takes to go over each sign or Rāshi, and consists of fractional and integral days; while that of the months in the latter is arbitrary, and consists of entire days which facilitate the calculation.

The Indian solar calendar, compared with the Luni-Solar is very simple; and probably it is on this account that it has been

* The correct number for tithi is 22·610. See example of Section 82.

adopted by our brethren dwelling in the eastern and southern maritime provinces. Undisturbed by adhika months, its dates are more in harmony with the seasons. As the days begin at Sunrise invariably, there is not much ado about the fixing of the socio-religious holidays. But the luni solar calendar, notwithstanding its inconveniences, is more phenomenal and attractive. Coming from the north and west, it has pushed the solar calendar towards the southern and eastern shores, and has forced its way to the sea between Vizagapattana and the mouths of the Krishna.

110 The Indian solar months and dates may be classified under two heads, viz. *The Bengal Orissa* and the *Tamil-Malayalam*. The former class exclusively follows the *Surya Siddhānta* and the latter the *Ārya Siddhānta*. In the first class, the dates are quoted in the *Bengali San* and *Vitāyati* eras while in the latter class they are cited in *Kaliyuga*, *Shaka* or *Kollam* eras.

111 The following is a list of *Solar Months* with their concurrent *Rashis* —

No	Rashis	Bengal Orissa S months	Tamil S months	Malayalam S months
1	Meṣa	Vaiśākha	Chittam	Medam
2	Mr̥ṣa	Jyestha	Vaikasi	Edavam
3	Mithuṇa	Āṣāḍha	Āṣi	Mithunam
4	Karka	Śrāvaṇa	Ādi	Karkāṭagam
5	Simha	Dhātr̥pada	Āvani	Chungam
6	Kanya	Āśvina	Purattasi	Kanni
7	Tula	Kārtika	Āṣvini	Tulam
8	Vriśchika	Mārgaśīrṣa	Kartikai	Vriśchikam
9	Dhanu	Pauṣa	Margali	Dhanu
10	Makara	Māgha	Tai	Makaram
11	Kumbha	Phālguna	Masi	Kumbham
12	Mina	Chaitra	Panguni	Meenam

THE BENGAL ORISSA SOLAR DATES

(In the calculation use Tables 3, 4, 13)

112. The object of this, as well as of the next, section is to enable the student to convert any Indian Solar date into its corresponding Christian date

Method—If the citation of the date contains the year of the Bengal San, it must be changed into the corresponding A.D. year by adding to it 593 years. (Table I.)

With the A.D. year as argument, take down from Table 3 the 2nd and 3rd elements of the required century, and add to them their increase for odd years given in Table 4, and add them up, taking care to cast out thirties from the Tithi-shuddhi when it exceeds thirty.

Below the sums write the increase up to the given Sankrānti or month, as given in Table 13, and sum them up. Thus we get the elements for the moment when the Sun enters the given sign or Sankrānti. Here we should pause a little and determine the English date on the first day of the Sankrānti according to the following *Bengal usage*.

(a) If the decimal fraction of the Vāra of the Sankrānti be less than 0.750, add its complement to the Vāra as well as to the English date. But if the fraction exceeds 0.750, increase the complement by unity before adding up. The sums will show the weekday and the English date current on the first day of the Bengal solar month.

Then add the remaining days of the solar month to the Vāra and the date, and determine the English month and date with the help of Table II.

(b) **The Orissa Usage**—In the case of Orissa where the Amāli and Vilayati eras are used, the decimal fraction of the Vāra of the Sankrānti should always be deducted from the Vāra

Example—Find out the A D year, month and date corresponding to the Bengal San 1317, Solar Māgha, 28th date
Here $1317 + 593 = \text{A D } 1910$

Explanation	A D	Vāra	A D date
Tab 3			
" 4	1900	4 620	A 12*620
" 4	8	3 070	0*070
	2	2 517	-517
Meshadi			
Tab 13 Māgha,	1910	3 207	A 13*207
Fraction 844 exceeds 750		2 637	27*637
Therefore add complement + 1		3 844	28*844
		1 156	1 156
On Māgha 1		0 000	290*
Add 27 to date and 6 to Vāra		6 000	27
On Māgha 28			
Tab 11 April 0 to February 0		6	317*
			300*
Ln. date Friday			11

Note—According to the usage of Orissa the date would be 9th February

The Tamil-Malayalam Solar Dates

(In the calculation use Tables 14 4 and 15)

113. The method of calculation is precisely the same as that of the preceding section. Only we must make use of Tables 14 4 and 15, instead of Tables 3, 4 and 13 of the Bengal-Orissa dates and attend to the following usage as regards the determination of the date of the first day of the Solar month

The Tamil and Malabar usage—If the decimal fraction of the Vāra at the beginning of the Sankranti be less than .500, the fraction should be deducted from the Vāra and the date. But if the fraction exceeds .500, its complement should be added to Vāra and the date, to get the same *i.e.* Vāra and date, on the first day of the solar month

The rest of the process is the same as before

Example—Find out the English year, month and date, corresponding to the Kollam Andu Era year 1085 (current), Dhano 20th. The Kollam year changes with Kanm after September 15 this case 1085 (expired) + .825 = A D 1910 (Table 1)

Explanation	A D	Vāra	A D date
Tab 14	1900	5 514	A 12 514
4	8	3 068	0 069
4	2	2 517	0 517
15 Dhanu		1 304	246 304
Fract on 404 is less than 500 By Malabar usage	1910	5 404 — 404	259 404 — 404
On Dhanu 1		5	259
Add 19 and 5 the change in Vāra		5	19
79		3	278
Tab 11 Apr 10 to January 0			775
Dhanu 70 = January 3rd	1911	Tuesday	3

The authors of the Indian Calendar state that the limiting fraction for the Malabar usage is 300. If this be the case the 20th of Dhanu would coincide with the 4th of January 1911.

Note—Although the determination of the first day of a solar month is not uncertain when the local usage is known yet it would be well for the people who use the Solar Calendar to mention the week day of their dates like the Arabs who use the lunar Calendar months the first day of which is decided by the actual appearance of the thin crescent. (See footnote to Section 132.)

Problem—To convert an A D date into the solar one.

114 The method of solving this problem is the reverse of that of the preceding sections 112 and 113.

Change the century year of A D by means of Table 1 to its corresponding Bengal San or into Kollam year as the case may require.

Find the Vāra and the date for the Meshadi of the given A D year by using Tables 3 and 4 in the case of the *Bengal* *Grishta* dates and Tables 14 and 4 in the case of *Tamil Malabar* dates. But when the date belongs to the month of January or February the Vāra and the date for the Meshadi of the preceding A D year should be used.

Find out by Table 11 the days elapsed from the beginning of the English month of Meshadi upto the given English

month and date and denote them by T. Deduct from T the days of Meshādi and call the remainder R.

Add to the date of Meshādi the days in Table 13 or 15 under column (3) that are next to but less than R, and the sum will mark the beginning of the Solar month.

Apply to the sum the correction of usage and determine the entire number of days on the first day of the solar month and deduct them from T and add 1 to the remainder. The result will denote the current Solar date.

Example—Calculate the solar date of the Bengal San corresponding to the 11th of February A D 1911.

Here the A D date being in the month of February, we should calculate the date of Meshādi of the preceding year A D 1910.

We deduct from Table 1 that the year A D 1900 corresponds to $(1900 - 593) = 1307$ of the Bengal San.

Also by Table 11 the interval from April 0 to the 11th February is 317 which we denote by T. Deducting the 13 days of April in the following calculation from 317 we get 304 for R.

On referring to Table 13 we see that under column 3 the number of days next lower to 304 is 275 637 which being added to the days 13 207 of Meshādi gives 288 844 days from April 0 to the beginning of the Magha month. Then adding 1 156 for Bengal usage we get 290 complete days for Magha 1.

English	B. Sa.	A. D.	Vara	A. D. date
Tab 1	1307	1900	5 62	1 10 60
4	8	8	3 57	0 020
4	2	2	2 51	0 517
Meshādi	1317	1910	4 70	1 13 207
13 Days of Maghādi < R less than R			7 63	275 637
Maghādi			6 84	288 844
B. gal usage			1 156	2 156
Maghādi	1		1 000	290 000
Tab 11 T				312 000
	72		6 00	72
Maghādi	72	date	000 00	290 000

VERIFICATION OF DATES THE TITHI

115 How the toil of computation can be minimised — In the preceding Sections we have described the methods of accurate calculation which deserve to be employed in cases of exceptional importance. No epigraphist however zealous and energetic he may be will be found willing to undergo so much trouble in each case. A simpler and shorter method is no doubt necessary even though it be at the cost of a little accuracy which is not always necessary in the work of verification.

This is possible if we calculate a given tithi by means of the solar elements of Table 13 using only two decimal places in the computation and the Supplementary Table 5 where necessary.

We might also dispense with the nicety of adding the Sun's equation of centre to the Moon's anomaly, the omission of which will at the most produce a variation of one ghata in the ending moment of the tithi.

THE NAKSHATRA

The mean value of a nakshatra current with a tithi can also be very easily derived by the following short formula

$$58 + (9 \times \text{tithi}) + (\frac{1}{4} \times \text{Sun's anomaly})$$

116 We shall present below one or two models of working without lengthy explanations assuming that the reader has fully mastered the theory and reasoning of the foregoing calculations. (I see Secs. 94-95.)

As a *first example* we shall test the accuracy and genuineness of the inscription at *Iran* which bears the date, Shaka year 406 Āshādha Shukla 12, Thursday (*Vide* Section 91)

We should calculate here the elements for the *Karka* *San* *Kranti* which is allied to Āshādha

Explanation	Shaka	A D	Tithi	Vāra	A D date	☾ anom	☼ anom
Tables							
3	32°	400	5 78	0 49	M 17 49	104° 2	260° 6
4	84	84	29 44	0 73	0 73	175 9	0 0
At Nimbādi	406	484	5 22	1 22	M 18 22	280 1	260 6
13			95 48	3 00	94 00	118 1	92 9
Karkādi			100 70	4 22	112 22	68 2	13 3
Completion			30	30	30	3 9	3
5			101 00	4 57	112 52	72 1	13 8
			1 00	0 35	0 95	12 9	1° 0
Āshādha Sh 12			102 00	5 30	113 50	80 0	14 8
				-0 03	-0 03		
				+ 41	+ 0 41		
Thursday				5 86	113 86	51 gh	36 pa
(1, March 6 to June 6)					92 00		
English date					21	June	

Similarly by the preceding formula

$$\begin{aligned}\text{The Nakshatra} &= 5 \cdot 8 + (9 \times 12) + (0 \cdot 75 \times 14 \cdot 8) \\ &= 5 \cdot 8 + 10 \cdot 8 + 1 \cdot 1 = 17 \cdot 7 = 18\text{th or Jyestha}\end{aligned}$$

Example 2—Verify the date Shaka 1106 on the day of *Shatabhishajya*, which was the 14th tithi of the first fortnight and Wednesday the 26th Solar day of the month of *Sinha*

This inscription is cited in *Epigraphia Indica*, Supplement to Vol VII p 132 as quoted by D B Pillar, Chronology p 74

Explanation.	Shaka	A D	Tithi	Nara	A D date	Os anom
Tables						
3	112 ^o	1 ^o 00	7 64	6 49	M 21 19	280 6
4	—16	—16	7 04	—6 14	—0 14	—0 0
Mesha ad	1106	1181	10 60	0 35	M 24 35	280 6
13			127 47	6 48	1 ^o 3 48	1 ^o 3
Sahād			178 07	6 83	149 83	44 3
Tamila age			17	17	0 17	0
1 of Sahān			134 21	0 00	150 00	44 3
7 (by Tab 11)			75 40	4 00	75 00	75 0
76 of Sah			167 64	4 00	175 00	69 3
Complement			36	36	36	0 4
Bhādrapada 14			164 00	4 36	175 36	69 9
11 March 0 to August 0					153 00	
The Mean tithi			ended	Wed	75 36	August 1

The Nakshatra = $58 + 126 + 52 = 238$ Shatabhishaja current

Note—The inscription is therefore correct in all its citations

117 The Samvatsara cycle of 60 years—Origin—This 60 year cycle probably had its origin in the approximate coincidence of the periods of the Jovian and Saturnian revolutions round the Sun. It is the smallest of the cosmic cycles at the end of which all the five planets assume very nearly the same geocentric configuration as they had at its beginning deviating on favourable occasions within six degrees one way or the other.

Use—Formerly people remembered the name of Samvatsara of the year in which they were born and when asked how old they were they replied by stating the Samvatsara of their birth. The Samvatsaras were also remembered as an aid to the memory of great calamities such as famines, floods and epidemics for instance the great famine of *Iskara Samvatsara* is named after it. The cycle also coincides with the ordinary span of human life. According to the Dharma Shastras a pious Hindu must perform the Shanti or penance on the completion of his 60th year.

Viewed from the point of public utility it must be considered unwise to break its continuity as is done in Northern India by adopting in its place the *Jorian mean sign system* which necessitates the suppression of 1 Samvatsara in the course of 85 years. The people of the Deccan have wisely adhered to the old custom of changing the Samvatsara regularly at the beginning of the year. At present the northern cycle has advanced over the southern by 12 Samvats on account of the suppression.

The cycle of 60 Samvatsaras seems to have been in use throughout India from remote antiquity. Aryabhatta says that he was 23 years old when 60 cycles of 60 years from Kali yuga had expired i.e. in Kali 3600. This implies that the 60 year cycle has been in use without any interruption or suppression for 50 centuries. We have shown in section 153 that the Indian and the Chinese 60 year cycles had probably a common origin.

118 To calculate the Samvatsara in the 60-year cycle.—Table 19 furnishes at a glance the Samvatsara current with a given A.D. year from the month of March to the end of December. If the given year be of the Shaka Era it should be converted into that of the A.D. Era by adding 78 to it.

The name of Samvatsara can also be found from table 19 when its index number is known.

The following three formulæ will be found useful in determining the Samvatsara independently of the Table 19.

$$\text{Samvatsara} = O (\text{Kali years} \div 13) - 60$$

$$= Q (\text{Shaka years} \div 12) - 60$$

$$= P (\text{A.D. years} \div 54) - 60$$

The symbol Q is used here in a new mathematical sense. The lower stroke is supposed to signify the remainder left after the division. In the above three formulæ the quantities within the brackets are to be divided by 60 and the remainder to be taken for the Samvatsara. For instance the Samvatsara for Shaka year 1840 is $52 = Q (1840 \div 12) - 60$ viz. the Kalyukta (Table 19).

CHAPTER XI

The Jovian mean-sign cycle of 60 Samvats used in Northern India

119 Probable Origin—The mean sign cycle of Jupiter alluded to in the *Surya Siddhānta* appears to belong to the period of *Samhitas* which preceded by many centuries the introduction of the *Siddhāntas* in India. But its re introduction into usage on the new basis of exact calculation appears to be comparatively later. This can be inferred from the fact that its commencement is quite abrupt in the list of *Samvatsaras* as it begins with *Vijaya* the 27th *Samvatsara*. The choice of the first year *Vijaya* appears to be deliberate as it is meant to impress the minds of the followers with its meaning of *sure Victory*. Bhaskaracharya defines the mean sign *Samvatsara* in the following manner —

वदस्यते यमराशिभोग सप्ततर सादित्वा वदोत् ॥

Here the word *Samhitika* appears to be used with the special object of pointing to its origin as much as to say that the introduction of the mean sign system originated with the authors of *Samhitas* and not with an astronomer. In our opinion the Jovian mean sign cycle serves no useful purpose but on the contrary it creates confusion and ambiguity in chronology not only by its two fold practices of being current either at the beginning of the year or at the date but also by the occasional suppression of years. One should like to see it replaced by its elder Deccan sister. (*vide* Sec 117)

Problem—To find the *Samvat* current at *Meshadi*
(*First Practice*)

120 The problem can be solved by the help of the following formula —

$$\text{Samvat} = 18\ 000 \div 1\ 0117 (\text{A D years} - 831)$$

Example—Find the *Samvat* current at the *Meshadi* of A D 1515

Putting the year 1515 in its place in the above formula and solving it we get—

$$\text{Samvat} = 18\ 000 \div 1\ 0117 (1515 - 831)$$

$$= 18\ 000 \div 1\ 0117 \times 684$$

$$= 50\ 008 = \text{The Subhanu in the list of Sec 122}$$

But this same result can be obtained by mere addition by means of Table 20, which we have borrowed from D B Pillai's Chronology. The theory of its construction will be found explained in Sec 121.

Rule.—From Table 20, part A take down the element for the century of A D era add to it the increase for odd years from part B, and cast out sixties from the sum. Refer the integers of the remainder to the list in Sec 122 and you will get the name of the Samvat current at Meshadi.

Example—Find out the Samvat current at the Mesha Sankranti of A D years 1514 and 1515

EXPLANATION	A D	SAMVAT
Tab 20 part A Samvat for	1500	34 832
„ B increase for	10	10 117
„ B, increase for	4	4 047
<hr/>		<hr/>
48 Vrisha at Meshadi of	1514	48 998
„ B increase for	1	1 012
<hr/>		<hr/>
50, Subhanu at Meshadi of	1515	50 008
<hr/>		<hr/>

The Samvats for the A D years 1514 and 1515 are Vrisha and Subhanu respectively. The Samvat 49 Chaitrabhanu having no touch with either is suppressed like the Kshaya tithi or the Kshaya month. This example illustrates the occasion when and the reason why it is necessary to suppress a Samvat.

121. We will now give the theory of Table 20 which is prepared by mere continuous summation.

Theory.—The length of a Samvat is the mean period in which Jupiter finishes one sign or 30 degrees. It is therefore equal to one twelfth of its mean periodic time, and is 361 0267 days. It is shorter than the sidereal year by 4 232 days. The result of this defect is that in 85 308 years there occur 86 308 Samvats. This superfluous Samvat is therefore to be suppressed like the tithi (Sec 35).

Samvat expired at Date Cited

(Second Practice)

123 In Northern India there is a second practice or mode of citing the Samvat which is expired not at the beginning of the year but at the date cited. This mode is more reasonable than the first, because it requires *no suppression* of a Samvat. This shows that thinkers soon after the innovation, realized the inconvenience and confusion arising out of the suppression. They must have therefore followed this second mode in preference to the first. But after all it was a bad innovation of a Samhitika meddling with the 60 year cycle of Samvatsaras which had been turning slowly and without jerks for many centuries. The people of the Deccan were however shrewd enough not to be lured by it.

Rule—When the first trial by Sec 120 fails to produce the cited Samvat we should calculate the interval from Meshadi to the date cited either in tithis or in days. Then we should divide the interval in tithis by 367 or that in days by 361 and add the quotient to the Samvat of the Meshadi. The result must agree with the citation. Otherwise the citation may be considered to be faulty.

Example—Verify the following date of a Sanskrit Manuscript given by its author as Shaka year 1396 Shubhakrit Kartika Shukla 9 Wednesday

Shaka 1396 concurs with A D 1474 from the Meshadi

Explanation	Shaka	Tith	A D	Samvat	Vern
Tab 20 A			1400	53 66 ⁷	
B			70	10 819	
B			4	4 047	
3	1322	0 610			6 04 ⁷
4	72	16 667			6 690
4	2	00 139			9 517
At Meshadi	1396	9 407	1474	8 5 ⁷ 8	1 389
The given T		219 000			
Interval in tithis	Tab 5	209 593	—367=	0 571	3 035
Samvat	Shubha	Krit	at date	9 099	4 674

Here the Samvat obtained for Meshâdi is 8 528, i.e., Plava (by the list in Sec 122). This does not agree with the author's citation. So we obtained the interval between the Meshâdi and Kârtika Shukla 9, which is 209 593 tithis. These divided by 367 gave the quotient 0 571, which, when added to 8 528 amount to 9 099. The integer 9 when referred to the list in Section 122 indicates the Samvat Shubhakrit, which fully corroborates the author's citation made according to the second practice. The week day was also Wednesday. Table 5 yields 3 235 as increase in Vara for Arg 209 513.

124. Name of the year in the 12 year Sub-cycle, as given in South India and Malayalam.—There are two more practices of naming a year in Malabar and Travancore. Their cycle is of 12 years and is based on the same principle. No separate calculation is, therefore, necessary, this cycle being itself a sub-cycle of the larger one.

In the third practice the year is named after the name of the sign obtained as remainder, after dividing the number of the Samvats by 12. According to this rule, the year Shaka 1396, cited in the preceding section receives the name Makara. Jupiter being then in the tenth sign (9 099).

This resembles the practice in the *Sankalpa* (vide sec 74), according to which one might say *Makarasthite De-agruau*. But in the *Sankalpa* the position of Jupiter is geocentric and not the mean heliocentric as calculated above. The difference, however, between the two positions of Jupiter never exceeds half a sign.

125. The fourth practice.—In this the names of signs are replaced by the names of those lunar months which derive their names from the nakshatras contained in those signs. The year is called Kârtika when Jupiter is in Mesha or the first sign, and Mârga Shukla, when in Vrihaspa or the second sign and so on with the prefix *Ma* to distinguish them from the ordinary lunar months.

In the preceding example the year 1396 was according to the fourth practice of naming *Maha Shrivara*. There is a good reason for this peculiar nomenclature. For, Jupiter occupying

the sign Makara rises and sets throughout the year called Mahā-Shrāvana along with the nakshatra Shravana (the bright star Altair, Alpha Aquila *vide* Fig. 1). Thus Jupiter is made to act like a hand in a clock, pointing to the Jovian years recorded on the sky-dial.

Example.—Let us verify the date of the following Malabar inscription by means of the mean position of Jupiter quoted in it: “Kollam 389, Jupiter in Kumbha, and the Sun 18 days old in Mīna.”

before commencing the calculation. These are the uncertainties that often beset the work of an epigraphist. When he is confronted with ambiguities and discrepancies like these he must try every alternative before pronouncing any date as incorrect or impossible.

D B Pillar in his *chronology* p. 64 cites an amusing case, apparently unaccountable, in connection with the solar date of the birth of a Tamil gentleman born at Belgaum in the Bombay Presidency. The date of birth in his horoscope was —

A D 1836 June 28 Ani 16'

while in all the Tamil panchangams the English date corresponded to Ani 17. This apparent paradox baffled all conjectures till it was explained by the fact that the Tamil astrologer who cast the horoscope at Belgaum did not know that the panchangam which he used at Belgaum was calculated according to the *Sūrya Siddhanta* and not the *Arya Siddhanta* as he believed. The difference was due to the difference in the times of Sankrāntis that changed the first day of the Ani month and subsequent dates by one and the same Tamil usage (see 113). This will be shown below —

Sūrya S [*]	A D	Date	Arya S [*]	A D	Date
ab 3	1800	A 10 745	Tyb 14	1800	A 10 646
4	56	0 490	4	56	0 490
13 Mithuna		6 ^h 308	15 Ani		62 376
	1836			1836	
Fraction greater than 500 Tamil usage		73 591 + 409	Less than 500 Tamil usage		73 482 — 462
Days from April 0 Tab 11 to June 0		74 61	From April 0 Tab 11 to June 0		73 61
Ani 1	June	13	Ani 1	June	1 ^h
15		15	16		16
Ani 16	June	28	Ani 17	June	28

Retrospect — Here we come to the end of our main object, viz., the treatment of the mathematical part of Indian chronology.

We have done our best to render the subject clear both from the practical and the theoretical points of view. But as no knowledge is rendered thorough and interesting without analogy and contrast we wish to acquaint our readers with the chronologies of other nations both modern and ancient.

A short allegory—Time is Nature's ever increasing wealth and a free gift. She bestows this favour without grudge or partiality on all nations and individuals both civilized and barbarous. Chronology is the system of keeping the account of the receipts of these gifts of Nature, and History and Biography are the accounts of the daily and yearly debits. The Calendars are the day books devoted to the entries of receipts only. The days months years and cycles are the coins and currency notes signifying the gifts of Nature which are made on the condition that they are to be debited the moment they are received and the balance to be nil every moment.

End of Part I

CHAPTER VII

127 The Musulman Calendar—The Calendar of the Musulmans is cyclic lunar. Their Era which is called the *Hijra* commences on Friday the 16th July 622 A.D. and corresponds to the Hindu date Shrawana Shukla 1 Shaka year 544. It commemorates the year of their Prophet's flight from Mecca which took place six months later in September in the month Rabi ul awwal.

The natural unit of time common to the Musulman and the Christian calendars is the *mean solar day* while that common to the Musulman and the Hindu calendars is the *mean lunar month*.

128 The length of their lunar month is 29 days 12 hours and 44 minutes exactly. They are therefore made to consist of 30 and 29 days alternately as shown in the subjoined table making in all 354 days for an ordinary lunar year and 355 days for a leap year.

Months	Days	Months	Days
1 Mubarram	30	7 Rajab	30
2 Safar	29	8 Shaban	29
3 Rabi ul awwal	30	9 Ramzan	30
4 Rabi ul akhīr or Rabi us sani	29	10 Shawwāl	29
5 Jumādālwāl	30	11 Zulhid	30
6 Jumādālakhīr	29	12 Zilhijja	29
		Do (In a leap year)	30

129 The cycle of 30 years —The outstanding 44 minutes which amount to 11 days in 30 years are distributed over the 11 years of the cycle of 30 years in the following order, 2nd 5th, 7th 10th, 13th 16th 18th, 21st 24th, 26th and 29th. This order of *leap years*, as they may be called by analogy, is adopted at Constantinople. They are so chosen that by the addition of the leap day to the last date of Zilhijja, the time of the mean visibility of the Crescent occurs always within 12 hours either before or after the sunset of the new year's day.

In some countries the years 8th 19th and 27th are considered as leap instead of the 7th 18th and 26th. But this change breaks the desirable condition of 12 hours and so deserves to be abandoned.

130 The beginning of the day, month and year —Among the Muslims the day is reckoned from sunset to sunset. The Moon is liked and respected more than the Sun. This may probably be due to the fierce glare and the intolerable heat of the latter in the sandy deserts of Arabia.

The month begins on the evening following the New Moon on which the faint and slender crescent is visible for the first time. This rule though applicable in theory to all the months alike, is practically observed in the determination of the first date

of the Muharram and Ramzân months. Our readers might have seen with what religious fervour the Musulmans watch from high places, on such occasions, the first appearance of the Moon's crescent and how joyfully they salaam each other at her first appearance.

$$\text{Monthly tithi} = \text{Hijri Tankh} + 2. \quad . \quad (a)$$

$$\text{Hijri Tankh} = \text{Monthly tithi} - 2. \quad . \quad (b)$$

Spread as they are from Morocco in the west to the Malay Peninsula in the east, the Musulmans trust only to the testimony of their own eyes, and decide the first day of Muharram and Ramzân for themselves. This is the reason why the Taboot day is sometimes celebrated on different days in different localities in India.

To calculate the Christian date corresponding to a given Hijri one.

(TABLE 21)

133. Method.—Deduct 1 from the number of the Hijri year and divide the remaining years by 30. The quotient and the remainder will respectively be the *cycles* and the *odd years* expired.

(a) From Table 21, parts B and C, given under the Christian Era take down the increase for the cycles, years, months and days, and add them. If the days in the sum exceed 365, divide them by 365, keep the remainder in the column for days and add the quotient to the years.

(b) Divide the A D years thus obtained by 4, and deduct the integral quotient from the days as a correction due to leap years.

(c) Add to the remainder the elements for the epoch in Part A. The sum will represent the years, days and week days according to the *Old Style*.

(d) Add 11, 12, 13, 14 and 15 days for the 17th, 18th, 19th, 20th, 21st and 22nd centuries respectively. The result will be the year and days according to the *New Style*.

Example—Required the A D year, month and date corresponding to the Hijri year 1337, Ramzân 1.

Here $1337 - 1 = 1336$ are the years elapsed, and dividing 1336 by 30 we get 44 cycles and 16 years.

Type of calculation

Explanation		Christian Era		
	Part Table 21	Years	Days	Vāra
(a)	B Increase for 40 cycles	1165	15	4
	4 ,	118	184	8
	C 16 years	15	195	0
	D Moharram 1 to Ramezan 1		230	8
		1296	630	15
	(830d = 1y 265 days) Total	1297	265	1
(b)	Deduct leap days 1297 -- 4 =		324	
	Total interval in Julian years and days	1296	306	1
(c)	A Epochal elements	677	198	6
	Sum date in old style	1919	137	0
(d)	Add for the 18th century		13	
	Sum date in new style	1919	150	0
	Days—January 1 to April 30 (by Table (b) of Sec 145)		119	
	Result 1919 May 31st Saturday	1919	31	0

To calculate the Hijri date corresponding to a given
Christian date

134 Method—(a) Deduct 621 from the given A D year, multiply the remainder by 365 and set down the product

(b) Divide the remainder by 4 take the integral quotient and write it below the product

(c) Also count the number of days from the beginning of the A D year not omitting the leap day of February if it intervenes, or use the table (B) in Sec 145

(d) Add up the numbers indicated by (a) (b) and (c) and deduct 561 days from the sum

(e) Then if the A D year be of the New Style deduct 11, 12 13 13 and 14 days for the 17th 18th 19th 20th and the 21st centuries respectively and call the remainder G But if the year be of the Old Style, nothing is to be deducted Thus G will be the number of days elapsed since the beginning of the Hijri Era, which we must now convert into Hijri years months and days

(f) From G deduct successively the highest possible number of days given in the columns headed Hijri Era in parts B C, and D of Table 21 Write down at the same time their respective equivalents in Hijri years and months The last remainder will be the day of the month

(g) Lastly add 1 to the number of years in order to change them into current year according to the Hijri Era

(h) The week day = $Q (G + 6) - 7$

Example.—Calculate the Hijri date corresponding to the 31st of May 1919 New Style

In this instance $1919 - 621 = 1298$ are the intervening years

	Days
(a) 1298×365	473 770
(b) $1298 - 4 =$ leap days	324
(c) January 1 to end of May 31	150
	<hr/>
Sum	474 244
(d) deduct the constant	— 561
(e) days to be suppressed for 19th century (New Style)	— 13
	<hr/>
G	473 670
(f) Deduct B 1200 years	— 425,240
	<hr/>
" B 120	48 430
	— 42 524
	<hr/>
" C 16	5 906
	— 5 670
	<hr/>
" D Muharram to end of Shābān	236
	235
	<hr/>
(g) Add $\frac{1}{\text{year current 1337}}$	Ramzan 1

Result.—The corresponding date was Ramzan 1, 1337 the year of the Hijri Era

The week day = $Q (473670 + 6) - 7 = 0 =$ Saturday

135 Mutual conversion of the Shaka and Hijri dates —
Students of the Mughal and Maratha periods of Indian History often require to know the corresponding dates of these two Eras. Table 22 is specially prepared for their use. It shows at a glance the number of the Hijri month concurrent with the Chaitra of Shaka years 1369-2049.

The Shaka years omitted in the table should be understood to begin with the Hijri month of the number attached to the preceding year. For instance the omitted Shaka year 1370 begins with the Hijri month 1 : i.e. Muharram; the years 1372-1373 begin with the Hijri month 2 : i.e. Safar and so on.

Problem —To find the fractional number of Hijri year corresponding to the Meshadi of the given Shaka year.

This can be solved by the following formula —

$$H = S - 518 + \frac{S - 1368}{32 \cdot 54}$$

Here H stands for the Hijri year and S for the Shaka year. The sign — means concurs with.

Example —What fractional Hijri year which begins with Muharram corresponds to the moment of the Meshadi of the Shaka year 1841. Here putting the Shaka year 1841 in the above formula and solving it we get

$$H = 1841 - 518 + \frac{1841 - 1368}{32 \cdot 54} = 1337 \cdot 51$$

= 1337 years and 6·5 months completed at the moment of the Meshadi.

This shows that the 7th month Rajab was running or was synchronous with the Chaitra of Shaka year 1841.

This fact is also confirmed by Table 22.

Now if it be desired to know what month of the Shaka year 1841 concurred with the Ramzân of the Hjrî year 1337, we might show it thus—

Shaka				Hjrî	
yr	m			yr.	m
1841	1	concurs with	.	1337	7
	2	add to each	..		2
1841	3	Jyestha	=	1337	9 Ramzân.

136. Problem 2.—Conversely to find the fractional number of the Shaka year corresponding to the New Moon of Muharram of the Hjrî year.

This can be solved by the following formula

$$S = H + 518 - \frac{H - 850}{33 \ 54}$$

Example—Suppose it is desired to know the Shaka year corresponding to the beginning of the Hjrî year 1337

Proceeding as before—

$$S = 1337 + 518 - \frac{1337 - 850}{33 \ 54} = 1840 \ 50$$

= 1840 Shaka year and 6 months which had elapsed at the beginning of Muharram

If we want to know what Hjrî month was running with the Shaka month Jyestha

Shaka				Hjrî	
yr	m			yr	m
1840	7	concurs with	..	1337	1
	8	add to each	.		8
1841	3	Jyestha	=	1337	9 Ramzân

Note—It may be noted that the above two formulæ are formed on the principle of *mean* intercalation while the concurrence shown in Table 22 is based on the *actual* calculation of the intercalary months. This difference may occasionally produce a difference of a month, which can be corrected with the help of Table 2 or 22.

137. The Arabic San or Sursan—The state papers and documents of the Maratha Period of Indian History always bear the years months and dates of the Arabic San coupled with Shaka months and titles

The following formulae show the relation between the Arabic, the Shaka and the Christian years

- (a) Fasah year = Arabic year + 9
- (b) Shaka year = Arabic year + 521 522
- (c) A D year = Arabic year + 599 600
- (d) Arabic year = Shaka year — 522 521
- (e) Arabic year = A D year — 606 599
- (f) Shaka year = A D year — 79 78

Note—We get two consecutive years from the above formulae. Of these the first concurs with the beginning and the second with the end of the given year in the second column

The Arabic San is Solar and like the Fasah year, begins at the moment when the Sun enters the Hindu *Mriga Nakshatra*. It is on this account sometimes called the *Mriga Sa*. Strange enough it has no months of its own and the defect is made up by the Lunar Hijri months current at date

Two formulae must therefore be combined one for the year and the other for the month

138 Problem—Given any Shaka year to calculate the Arabic year and the Hijri month current at the moment of *Mrigādi* which occurs in the Hindu month of *Jyestha*

$$(c) \text{ Arabic year} = \text{Shaka year} - 522-521$$

$$(H) \text{ Hijri month} = \text{The fraction of } \left(\frac{\text{Shaka years} - 1493}{32-54} \right) \times 12$$

Example 1—Find the Arabic year and Hijri month and date at the moment of *Mrigādi* in Shaka year 1812

As the Arabic year which began with Mrigādi of the Shaka year 1842 was the latter one, we must make use of the latter number 521 in Formula (e).

The required Arabic year is $1842 - 521 = 1321$.

And by formula (H) of § 138

$$\frac{1842 - 1493}{32 \cdot 54} = 10 \cdot 725 \text{ of which—}$$

the fraction $\cdot 725 \times 12 = 8 \cdot 7$ months (Iḥjri).

= 8 months, 21 tithis.

By Sec. 132, Formula (b) = 8 months, 19 tarikhas.

= 9th month Ramzān.

current at Mrigādi.

Ans—Arabic San 1321, Ramzān 19th tarikha.

139. The Arabic notation of years.—The Arabic years are often expressed in words, and very seldom in figures. The following words express the numerals which precede them :—

1 Ihide	8 Sammān	60 Sectain
2 Isanné	9 Tissā	70 Sabbain
3 Sallās	10 Ashar,	80 Sammāneen.
4 Arbā	20 Ashareen	90 Tissain.
5 Khamas	30 Sallaseen	100 Mayyā.
6 Seet	40 Arbain	200 Mayyātain
7 Sabbā	50 Khamsain	1000 Alaf.

Example 2—Find the tithi, month and year of the Shaka Era corresponding to 14th tarikḥ of Rabi-ul-awwal of the Arabic or Sursan year Sallāseen, Mayyā, and Alaf = $30 + 100 + 1000 = 1130$. (Given in Art. 44, Part VI, Materials for the History of the Marathas by Rājwade.)

Arabic year $1130 + 521 = 1651$ Shaka, (Sec. 137)

On referring the Shaka year 1651 to Table 22 we find that the Chaitra corresponds to Ramzān the 9th, so that when counted from the Muharram of the preceding year, Rabi-ul-awwal is the 15th month, and the 14th tarikḥ corresponds to the 16th tithi.

Deducting 9 from these lunar months, we get 6 months and 16 tithis, and counting from Chaitra Shukla 1, we come to Ashvin Krishna 1 of the Shaka year 1651, which is the tithi sought

Example 3.—Find the Christian date, month and year corresponding to Jyākad 1 of the Arabic year Sammān, Sabbān Mayyā, and Alaf = $8 + 70 + 100 + 1000 = 1178$ (Given in Art 159 of letters etc. collected in the Kāvyaśāhasa Saṅgraha)

Arabic year $1178 + 599 = 1777$ A D (Section 137) $1178 + 521 = 1699$ Shaka (Sec 137)

On referring the Shaka year 1699 to Table 22 we find that the 3rd month Rabi' ul awwal concurs with the Chaitra. Deducting the 3rd month from Jyākad the 11th, we get 8 months and $1 + 2 = 3$ tithis or 243 tithis in all. Counting from Chaitra Shukla 1, we arrive at Mārgashīrṣa 3. We may now calculate the English date corresponding to Mārgashīrṣa 3 of Shaka year 1699 according to Sections (77—81)

Or we may calculate the approximate English date with Table 23, as shown below—

Explanation	Shaka	A D	Tithi	Date	Vāra
Table 23	1698	1776	-1 0	1 p 0 5	3 5
Table 23 bottom figures	1	1	11 1	0 3	1 3
At Meshādi	1699	1777	- 1	9 8	4 8
Table 5 complement of 243			240 9	237 2	6 2
Mārgashīrṣa 3			243 0	247 0	4 0
Tab 14 April 0 to December 0				244 0	
Result Wednesday	1699	1777	Dec	3 0	4 0

CHAPTER XIII

THE CHRISTIAN CALENDAR

140 History of the Calendar.—We take the following description from 'Outlines of Astronomy' by J F W Herschel—
The history of the calendar, with reference to chronology or to

the calculations of ancient observations may be compared to that of a clock going regularly when left to itself but sometimes forgotten to be wound up and when wound sometimes set forward sometimes backward either to serve particular purposes and private interests or to rectify blunders in setting. Such at least appears to have been the case with the *Roman Calendar* in which our own originates from the time of Numa to that of Julius Cæsar when the Lunar year of 13 months or 355 days was augmented at pleasure to correspond to the solar by which the seasons are determined by the arbitrary intercalation of the priests and the usurpations of the decemvirs and the magistrates till the confusion became inextricable. To Julius Cæsar assisted by Sosigenes an eminent Alexandrian astronomer and mathematician we owe the neat contrivance of the two years of 365 and 366 days and the insertion of one bissextile after three common years. This important change took place in the 45th year before Christ which he ordered to commence on the 1st of January being the day of the New Moon immediately following the winter solstice of the year before. We may judge of the state into which the reckoning of time had fallen by the fact that to introduce the new system it was necessary to enact that the previous year 46 B. C. should consist of 445 days a circumstance which obtained for it the epithet of *the year of confusion*.

(a) But the real length of the tropical year is 365 24224 days and the yearly excess of about 00776 day amounted during the next four centuries to three days. Consequently the equinox had retrograded from the 20th to the 21st of March. At the Council of Nice in A.D. 325 it was enacted that the 21st of March should in future be the day of the vernal equinox but no remedy was suggested to check the ever accumulating error. During the Popedom of Gregory XIII the equinoctial day owing to the unchecked excess actually fell on the 11th of March which was quite against the enactment of the Council of Nice. The amount of the annual error being then correctly ascertained to be about three days in four centuries Pope Gregory XIII ordered that the 11th of October 1582 should be followed by the 10th of October and not by the 5th. Consequently the equinox again fell on

the 21st of March in A D 1583. But the year 1582 consisted of 355 days only.

(b) In order to secure the perpetual concurrence of the Vernal Equinox and the 21st of March the Pope further enacted that the century years that were not divisible by 400 without a remainder should be considered as ordinary years although they were divisible by 4. Thus the century year 1600 is a leap year but the years 1700 1800 and 1900 are not leap years the number of days of February in these years is 28. The year 2000 will be a leap year and the years 2100 2200 and 2300 will be again ordinary years consisting of 365 days.

This change is called the *New* or the *Gregorian Style* as distinguished from the *Old* or the *Juban Style*. The New Style was at once adopted in all the Catholic countries. But England hesitated till the year 1752 A D and finally adopted it by an Act of Parliament. The 2nd day of September 1752 was the last day of the Old Style in England and the first day of the New Style was the 11th instead of the 3rd. 11 nominal days being struck out.

(c) The same legislative enactment which established the Gregorian year in England in 1752 shortened the preceding year 1751 by a full quarter. Previous to that time the year was held to begin with the 25th March and the year A D 1751 did so accordingly but that year was not suffered to run out but was supplanted on the 1st January by the year 1752 which (as well as every subsequent year) it was enacted should commence on that day so that the English year 1751 was in effect an *annus confusionis* and consisted of only 282 days.

Russia was the only country in Europe in which the Old Style was adhered to and (three secular years having elapsed) the difference between the European and Russian dates amounts to 13 days at present (A D 1920). But the Russian republic has now given up the Old Style.

The change of calendar in England met with much popular opposition. The day labourers complained that they were unjustly deprived of their wages for eleven days and the young ladies murmured that they were made older by the change.

141. Astronomers are justly opposed to such sudden and abrupt changes in the calendar. Simon Newcomb says in his *Popular Astronomy* "the length of the mean Gregorian year is 365d 5h 49m 12s, while that of the tropical year, according to the best astronomical determination, is 365d 5h 48m 46s. The former is, therefore, still 26s too long, an error which will not amount to an entire day for more than 3,000 years. If there were any object in having the calendar and the astronomical year in exact coincidence, the Gregorian year would be accurate enough for all practical purposes during many centuries. In fact, however, it is difficult to show what practical object is to be attained by seeking for any such coincidence. It is important that summer and winter, seed time and harvest, shall occur at the same time of the year through several successive generations; but it is not of the slightest importance that they should occur at the same time now that they did 5,000 years ago, nor would it cause any difficulty to our descendants of 5,000 years hence if the equinox should occur in the middle of February, as would be the case, should the Julian Calendar have been continued.

The change of calendar met with much popular opposition, and it may hereafter be conceded that in this instance the commonsense of the people was more nearly right than the wisdom of the learned. An additional complication was introduced into the reckoning of time without any other real object than that of making Easter come at the right time."

142. The interval in days elapsed.—The chief object of chronology is the calculation of the exact number of days, that have elapsed since the Epoch of an era, or between any two given dates separated by a long interval. The Musulman calendar is better suited for this purpose. It is not liable to any uncertainty excepting the one due to the first visibility of the crescent moon after the New Moon. The error due to this cause would never amount to more than a single day, and can be easily corrected by the week-day if available. (*Vide* footnote to Sec. 132.)

Next to it in the matter of convenience are the Indian luni-solar and solar calendars. But the former is liable to an uncertainty of a full month when the mean intercalary month is made

use of in the calculation. The solar calendar is the best as it is based on the number of days in a sidereal year and is not hampered by the *Adhika* and *Kshaya* months. Yet the solar dates are sometimes rendered doubtful by the different usages in different parts of India as regards the determination of the first day of a month. *Vide* Sections 112, 113 and 126.

143 The Julian Period—To avoid confusion in chronology the astronomers and chronologists have invented and adopted a new cycle of 7980 Julian years called *The Julian Period*. It has been found so useful that the most competent authorities have declared that through its employment light and order were first introduced into chronology. It was invented or revived by Joseph Scaliger, who is said to have received it from the Greeks of Constantinople. The first current year of the Julian period was 4713 B.C. and the noon of the 1st of January of this year for the meridian of Alexandria is the chronological epoch to which all historical eras are most readily and intelligibly referred by computing the number of integer days intervening between that epoch and the noon (for Alexandria) of the day. The meridian of Alexandria is chosen as that to which Ptolemy refers the commencement of the era of Nabonassar, the basis of all his calculations. The number 7980 is obtained by the multiplication of the numbers 28, 19 and 15, which are severally the Julian years in the Solar, the Metonic and the Indictional cycles. This cycle consists of years and days only and resembles the smaller cycles of the *Grahala* and *Kataka*, which consist of 4016 and 6940 days respectively.

144 The leap year how determined—To determine whether a given Christian year is leap or not proceed thus—

OLD STYLE

B. C. years—Deduct 1, divide by 4 and if no remainder be left it is a leap year.

A. D. years—In England the Old Style had been in use upto the date September 2 (inclusive) 1752 A.D. So the A.D.

years preceding this date are leap, when they are divisible by 4 without remainder.

NEW STYLE

A. D. years.—The New Style came into force after the above date. It is exactly the same as the Old one, differing from it by a single exception, which is that century years which are not divisible by 400, although divisible by 4 without a remainder, are not leap years but common years, *i.e.*, the days of February in them are 28. For instance the years 1700, 1800, 1900, 2100 are common years.

Note.—A counter correction to this rule is proposed. It is that years divisible by 4000 ought to be considered as common years.

Because 4000 tropical years contain,	Days
according to Newcomb $365.2422^{\circ} \times 4000$	= 1460969
„ Gregorian Reformation—	
$365 \times 4000 = 1460000$	
Leap days 970	
<hr/>	= 1460970

To calculate the number of days elapsed since the Julian epoch, corresponding to any given date, old style

Find the number of the Julian years (J P) elapsed as above and multiply them by 365

Add to these the leap days obtained by adding 3 to the Julian years elapsed and dividing them by 4

Add also the number of days intervening between January 1 and the given date from Table (B) on p 100

Example — Find the interval in days between the commencement of the Julian Period and that of the Kali yuga February 18 3102 B C

Here the years elapsed are $4713 - 3102 = 1611$,

	Days elapsed
1611×365	588015
$(1611 \div 4) - 4 = \text{leap days}$	403
Days elapsed Jan 1 to Feb 18 Tab (B)	48
At the Epoch of the Kali yuga	<hr/> 588466 <hr/>

To find the same for any given date of the *New Style* proceed as above considering the date as a Julian date Then from the resulting days subtract as follows —

	Days
For any date (N S) before March 1 A D 1700	10
After Feb 28 1700 and before March 1 A D 1800	11
1800	12
1900	13
	2100

Examples 2 and 3 — Find the number of days elapsed of the Julian Period on Sept 1st B C 1193 and April 3 A D 1878 which are the Epochs of the Aryan and Ketaka Eras

Here the years elapsed are $4713 - 1193 = 3520$ and $4712 + 1878 = 6590$ upto the two Epochs respectively

Example 2

	Days elapsed
3520×365	1284800
$(3520 + 3) - 4 = \text{leap days}$.. .	880
Jan 1st to Sept 1st, Table (B) p 100 ..	244
	<hr/>
Epoch of the Aryan Era .. .	1285924
	<hr/>

Example 3

6590×365	2405350
$(6590 + 3) - 4 = \text{leap days}$	1,648
Jan. 1st to April 3rd, Table (B) p 100 ..	92
	<hr/>
	2407090
Correction for New style	- 12
	<hr/>
At the Epoch of Ketaki, see next page	2407078
	<hr/>

To find the week-day of any Julian date.—Add 2 to the number of the days elapsed, and divide the sum by 7, and count the remaining days from Sunday as one. The result will be the week-day

In the above example adding 2 to 2407078 and dividing 2407080 by 7 we get 4 as remainder, and counting from Sunday we get Wednesday for the Epoch of Ketaki

By following the same course we get Friday for the Epoch of the Kali yuga

Intervals in days between the commencement of the Julian Period and that of some other remarkable chronological and astronomical Epochs.

TABLE (A)
of important Epochs partially derived from J F W
Herschel's Outlines of Astronomy

Names of Eras and Epochs	First day of Era	Chronology B C	Julian Period years	Interval in days elapsed
Julian Period	January 1	4713	1	
Kali yugae (Era of the Deluge)	February 18	3102	161*	588 468
Epoch of Aryan Era*	September 1	1193	3521	1985974
Olympiads	July 1	776	3938	1433171
Era of Nabonassar	February 26	747	3967	1448638
Relapse of Thales	May 28	585	4129	1807900
Metonic Cycle	July 15	432	4282	1563831
Julian Reformation	January 1	B C 45	4660	1704987
Dionysian Era	January 1	A D 1	4714	1721424
Hijra (New Moon)	July 15	622	5335	1948438
Era of Yezdgird	June 16	632	5345	1952063
Last day of old style	September 2	1752	6465	2361221
Epoch of Kataka*	April 3	1878	6591	2407078

* See page 99

TABLE (B)
Days elapsed from Jan 1st to the 1st of each month

Months	In a common year	In a leap year	Months	In a common year	In a leap year
January 1			July 1	181	182
February 1	31	31	August 1	212	213
March 1	59	60	September 1	243	244
April 1	90	91	October 1	273	274
May 1	120	121	November 1	304	305
June 1	151	152	December 1	334	335

146 Perpetual Almanac for the European Calendar — The perpetual Almanac enables us to find the week day or *Vara* of any English date. In fact it is a means of testing the accuracy of a date by casting out sevens in the same manner as we test the accuracy of a product by casting out nines. It is given in several forms but here we have adopted that in which it is given by D. B. Pillai in his *Chronology* for the sake of its great simplicity. See table 24.

147 The Index-numbers — The numbers in heavy type printed at the tops of the columns of centuries, years and months in Table 24 may be called the *Index numbers*. They are common to all the numbers of years and months shown in the column below them. The index number for the days of a month is the remainder left after dividing them by 7.

148 To compute the week day of a given Christian date stated in A. D. years

Rule — All that we have to do is to add up the Index numbers of the four component elements of time viz. the century, year, month and date of the given day as shown in Table 24 and to cast out sevens from the total if it exceed 7. The remaining Index number will show the week-day beginning with Sunday as 1.

Example — Required the week day on June 10 1858

By Sec. 144 the year 1858 is not leap

			Index
Table 24 the Index of A D	1800	century	4
"	"	" 58 years	2
"	"	" 6 June	3
"	"	" 10 days	3
The required week-day is Thursday			5

149 Rule in the case of B. C. years — In calculating the week-day of a B. C. date the given B. C. year should be deducted from the last preceding century and the remainder should be used as odd year.

Add to the Index of the last preceding century, the Index of the odd year thus found and that of the month and of the date as before

Example.—Required the week-day of 18, February 3102 B C, which was the first day of Kaliyuga

By Sec 144 $Q(3102 - 1) - 4 = 1$ It is therefore a common year

	Index
Table 24 Index of B C 3201 (the last preceding century)	3
$(3201 - 3102) = 99$ odd years	4
February in ordinary year	2
18 days of month	4
	<hr/>
The Kaliyuga began on Friday	6

150 Theory of the formation of the perpetual calendar.—A century consists of 36525 days or 5218 weeks minus one day. This is the reason why the B C centuries advance and the A D centuries recede along the Index numbers

An odd year when not leap, consists of 52 weeks plus one day. This fact explains why the odd common years advance along the Index numbers

As the first year A D and the first date of January began at the same moment on Saturday the Index of which is zero (0) the zero date of January :c December 31 must have 6 for its Index

NOTES ON WEEK-DAYS

Use—The cycle of week days like the decimal notation has been adopted by every civilized nation. It is to the illiterate what the cycle of Samvatsaras is to the educated. A day is too short and a month is too long for common people to count and remember. The market days, the payment of wages to the day labourers, the recovery of interest for small money lending business, the periods of the prescription of medicine and similar short terms and engagements are most conveniently regulated by means of the weeks

The week is a little calendar solely dependent on human memory, and incapable of being determined from observation of the heavens.

The origin of the week-days.—The origin must be ascribed rather to the astrologers than to the astronomers. For the order is governed by the supposition, or rather superstition, that each of the 24 hours of the day is ruled by the planets by turns, according to the descending order of their Periodic times, *viz.*, Saturn, Jupiter, Mars, the Sun, Venus, Mercury and the Moon, when written so as to complete a circle. It is plain then to see that if Saturn should preside over the first hour of a day, it will preside again over the 8th, 15th and 22nd hour, and then it will be the Sun's turn, occupying the third place in the cycle from Saturn to preside over the 25th, or the first hour of the second day, and the Moon's turn to preside will be on the first hour of the third day and so on.

The *Sūrya Siddhānta* briefly explains the above theory of the week-days in the following verse.

मन्दारवः क्रमेणसप्ततुषां दिवसादिषाः ॥ ७८ ॥

होरेषाः सूर्यतनयादघोषः क्रमशस्तथा ॥ ७९ ॥

(भूगोलाध्याय १२)

Meaning—From Saturn downwards every fourth in the (cyclic) order is the lord of the day. From Saturn downwards in due succession they are each the lords of the hours.

CHAPTER XIV

BRIEF NOTICES OF OTHER LUNI-SOLAR AND SOLAR CALENDARS

(1) The Vedic Calendar

151. The vedic Calendar is one of the most ancient, being compiled in the fourteenth century Before Christ. Each Veda had its own Jyotisha. The *Rigveda Jyotisha* consists of 36 verses and the *Yājusha Jyotisha* of 43, of which 30 verses are common

to both. Most of them are very unintelligible. Messrs J B Modak, S B Dixit B G Tilaka Bārhaspatya and others have tried to interpret them in their own way. But there are still a few verses which have baffled all their attempts at explanation.

(a) Its primary object was to announce to the village cultivators the progress of the seasons and the fortnightly and other sacrifices were but a means to gain this chief object. The Agnihōtris, who were much esteemed and amply provided with corn and other necessaries kept up a regular watch over the movements of the sun observing the Equinoctial and Solstitial days every year.

By this course the Agnihōtris soon came to know that the seasons happened regularly with respect to lunar months in the course of 5 years. Thus the Aryan Agnihōtris established the five year cycle which contained 60 solar months 62 lunar months 67 lunar revolutions 1830 solar days and 1560 titlis. They were also clever enough to mark that the Sun and the Moon turned towards the north after reaching the Dhāniśthā Nakshatra (Alpha Delphinus).

(b) The first year of the opening cycle began with the New Moon which fell on the day of the winter Solstice. The chief object of the calculations was to determine the lunar titlis and months on which the bi-monthly seasons the Equinoxes and the Solstices occurred in each of the five years and as a course preparatory to determine the days (titlis) of the above phenomena it was necessary to calculate at first the position of the Sun accurately with respect to the Nakshatra Divisions for each of the 124 New and Full moon days in the cycle. This is the same method of calculation which is followed in the preparation of the Nautical Almanacs, in which the positions of the Sun and the planets are calculated first, and the table of phenomena calculated with them is placed at the end.

The notions being mean, Mr S B Dixit has embodied the preparatory course at pages 77 and 78 of his Marathi History of Astrology and the phenomena are stated at pages 91 and 75 as described in the Garga Samhitā.

(c) In fact this little cycle of 5 years was far from being perfect. For the defect of the lunar year as compared with the solar year is 11 tithis which amount to 55 tithis at the end of the fifth year. By intercalating two lunar months we intercalate 5 tithis more than what is required. In other words we add unnecessarily one tithi per annum and unless there is a provision to get rid of this excess the cycle must become useless after 30 years.

But as we meet with references and allusions made about the cycle in the Mahabharata and its use in the Pitamah Siddhanta which was in use in A.D. 80 there must have been a proviso for the removal of the undesirable excess in intercalation when it amounted to a whole month in 30 years by omitting the 12th intercalary month. But unfortunately the verse containing the correction has somehow disappeared along with others from the text of the Vedāṅga. We can however infer the existence of such a proviso in the following definition of the *Adiyuga* i.e. the first cycle which fulfilled the original conditions of the Epoch after every 30 years.

स्वराष्टमेने सोमाहो यदा साक सप्तशती ।

स्वान तदाऽऽदियुग मापस्य गुणोऽप्यन्यत् ॥

(d) The presence of this correction is clearly traceable in the following verses in the Mahabharata. —

देवा द्वाविंशतिवैष प्रवोदितस्य च व्यतिरेकमात्रं

पचमे पचमे षष्ठे द्वौ मासावुपजायत ॥ १ ॥

एवमभ्यधिका मासा पच च द्वादश शुभः

प्रवोदमाना पचागच्छन्ति मे वदते मति ॥ ४ ॥

पूर्वपुरेण निर्णतस्वतो नामगुणान्त

विराटपतेः शब्दात् ५१

Here the word सप्त is irrelevant to and irreconcilable with the meaning intended by the speaker Bhishma. There is no question at all about the nights. I think that the word सप्त was originally सप्त * but was mistaken by the scribe for we

* A copy (No. 42, Vashraha I fol. 63) in Phandakar's Research Inst. actually reads — "पचम्य द्वादश सप्त ॥ ४ ५ ॥" This copy makes full distinction between ४ and ५.

often meet with instances of व mistaken for व. Also शत seems to be used for चतुर्विंश for the exigency of metre. With this emendation the above verses state with astronomical accuracy that 13 solar years (s) are equal to 13 lunar years (l) plus 3 intercalary months minus 13 tithis. This can be stated algebraically—

$$\begin{aligned} 13 s &= 13 l + 5 \text{ months} - 13 \text{ tithis} \\ 30 s &= 30 l + 12 \text{ months} - 30 \text{ tithis nearly} \\ &= 30 l + 11 \text{ months} \end{aligned}$$

(c) The above demonstration clearly shows that the rule of omitting or suppressing every 12th intercalary month must have been in practice in the time of the Mahabharata. This resembles the Gregorian rule in connection with the omission of leap days. We sometimes meet with allusions to kshaya months in the age of cyclic calculations. In such cases the kshaya months must be no other than the omitted intercalary months.

The above rule can be also deduced from astronomical data

$$\begin{aligned} s &= 371 \text{ } 0\text{ } 0\text{ } \text{ tithis (page 210)} \\ \text{or } s &= (360 + 12 - 1 + 0 \text{ } 0\text{ } 5) \text{ tithis} \\ 30 s &= 30 (360 + 12 - 1 + 0 \text{ } 0\text{ } 5) \text{ tithis} \\ &= 30 l + 12 \text{ months} - 1 \text{ month} + 1 \text{ } 5 \text{ tithis} \\ 600 s &= 600 l + 20 l - 20 \text{ months} + 1 \text{ month} \\ &= 600 l + 221 \text{ intercalary months} \end{aligned}$$

So I suggest that the following two verses composed by me may be read, in place of the missing ones immediately after the 37th verse of the Yajus Jyotisha beginning with यद्विंशतिनामाना वरा पर्वणि पर्वणि. By this means the Vedanga Jyotisha Cycle can be used for sacrificial purposes even at the present day, if its epoch is known which is probably B C 1440 = 1193 + 247 (*vide* sec 152)

विद्वान् युगपत्काले ६ प्राज्ञ मास एलिम्बुनम्
 प्राग्मेत तदाऽऽद्यानि युगानि च पुन पुन ॥ ३८ ॥
 न ह्येव पञ्चाशत्दीप्तो ६०० मासमासोऽधिकस्तु य
 एवमादेवगृह्यमो योमयकाले एता भवेत् ॥ ३९ ॥

(f) We shall finish this brief notice of the Vedānga Jyotiṣha by mentioning the fact that it has rendered the greatest service to the cause of *Indian antiquity* by recording the position of the Solstitial points in its time. This has led to the fixing of its date as 1400 B.C., and also of other dates of the Vedic literature relatively to it.

Professors Max-Müller, Whitney and others have in vain tried to reduce this impregnable stronghold of Indian Antiquity (vide Max Müller's preface to the 4th volume of his *Rigveda Samhita*)

(g) It appears that the sage by name Lagadha was the original author of a small tract on the Vedic calendar and that the Vedānga Jyotiṣha was simply an adaptation of it as the following opening verse clearly shows.—

प्रथम्य विष्टा बाल अभिरात्र मत्स्यनीम्
 बालान्नम प्रवक्ष्यामि रगधस्य महात्मन ॥

The title कालज्ञान literally means knowledge of time, the same as the French title 'Connaissance des temps'. This shows how true ideas concur although the thinking minds may be separated by thousands of years.

Calculations made on the basis of the greatest length of the day, stated by Lagadha, show that he lived in latitude 35 degrees North probably in Cashmere.

(2) The ancient Indian or Aryan Calendar
 (In use from 1193 B.C. to 291 A.D.)

152. To me it had been a great puzzle to understand how the ancient Indian kings could have managed their state affairs for centuries without a well-regulated calendar and an era for its basis until I saw the following table given by John Bentley in his *Historical View of the Indian Astronomy*. Being given in a rudimentary form and without any directions regarding its use, the table has hitherto failed to attract the attention of scholars.

But I found it fully practicable and therefore thought it worth while to recalculate it with a view to detect errors in it and to amplify it by placing alongside other concurrent Indian eras

Table showing the Ancient Aryan Tropical Solar Calendar

Cy- cles	Christian Chronology			Aryan Chronology				Siddhantic Chronology	
	B.C.	Mon	Date Day	Year	Month solar	Sun	Spica	Kali	Shaka Mon tithi lunar
					long	long	long		
1	1193	Sept 1	Thurs 1285924 J P	0	Asvin ☾ 222°	150°	160	1909	—1270 Bhad 6
2	946	Oct 1	Satur 1376170 J P	247	Kārtik ☾ 252°	180	163	2156	—1073 Āvin 6
3	699	Oct 29	Sun 1466415 J P	494	Mārga ☾ 282°	210	166	2403	—776 Kārtik 6
4	452	Nov 27	Tues 1556661 J P	741	Paush ☾ 312	240	170	2650	—529 Mārg 6
5	205	Dec. 25	Wed 1646906 J P	988	Māgha ☾ 342	270	173	2897	—282 Paush 6
6	A.D. 44	Jan 24	Fri 1737152 J P	1235	Phalg ☾ 12	300	176	3145	—34 Māgh 6
7	291	Feb 21	Satur 1827397 J P	1482	Chaitr ☾ 42°	330	180	3392	+213 Phalg 6 ended at 86 gh

Note—J P—Days of the Julian Period expired at Sunrise

(a) The opening tithi of the 1st cycle was called Adikalpa shasthi that of the 2nd Gūha shasthi that of the 3rd, Vītra saptami which we at present call Ratha Saptami

The following are the ancient constants and elements with which the above table is computed In a cycle —

Sun's tropical revolutions	247½	Mean solar days	90245 5
Moon's do	3303½	Lunar tithis	91680 0
solar months	2965	Precession seconds	12000 0
Lunar months	3056	Tithis in a solar month	30 9205
Intercalary months	91	Days do do	30 4368

The following ancient values are obtained from the preceding elements for comparison with the modern ones :—

Length of—		Ancient.				Modern.			
		Days	H.	M.	S.	Days	H.	M.	S.
Tropical year	..	365	5	50	10	365	5	48	48
Sidereal year	..	365	6	9	53	365	6	9	9
Lunar month	..	29	12	44	3	29	12	44	3
Moon's revolution	..	27	7	43	5	27	7	43	5
		Days.				Days.			
247 $\frac{1}{4}$ tropical years	..	90245.5				90245.26			
3303 $\frac{1}{2}$ —Moon's trop. revolu.		90245.5				90245.723			
Yearly precession	..	48".567				50".236			

(b) This Aryan cycle of 247 $\frac{1}{4}$ tropical years is really a happy combination of the lunar, solar, and sidereal systems. It contains 13 metonic cycles and one month. Each new cycle begins invariably on the 7th tithi of the month next to that with which the preceding cycle has begun. The precession of the equinoxes in one cycle amounts exactly to a quarter of a Nakshatra, and the 7th cycle begins in the year A.D. 291, in which the tropical longitude of the brilliant and conspicuous star Spica (*Chitrâ*) was exactly 180 degrees, as mentioned in the old *Surya S.*, quoted in the *Pancha Siddhântikâ*. [*Vide sec. 200 (a).*]

It completely fills up the hitherto supposed chronological gap of fifteen centuries, separating the *Vedāṅga* and the *Siddhānta* periods. This calendar must have been in general use while the five-year Vedic calendar was used only for sacrificial ceremonies. But the cycle was not destined to run for ever. It appears probable that soon after the star Spica had coincided with the autumnal equinox, the Babylonian astronomy appeared in India and threw into the background the ancient Indian chronology. Learned men were willing to adopt it but the orthodox, as was natural, strongly opposed it. Thus the *Romaka* and *Paulish* works commented on by *Lātādeva* were rejected as being *apauruṣeya* i.e., opposed to the scriptures. The efforts of *Shrīshena* and *Vijayananda* shared the same fate.

(c) At last Āryaṇātha* or his predecessor or some unknown contemporary astronomer realised, it appears, the necessity of gratifying the orthodox in the manner of children crying for the Moon. He adopted in his Siddhānta the era of Kalyuga and its colossal multiples, the Mahāyugas and the Kalpa. Computing backward with the correct mean motions of the Sun and the moon from the Kali year 3600, he arrived at *Shukla saptaṃsi*, as the tithi of Mesha Sankrānti in the zero year of the Kalyuga. This result was very disappointing to him. For he wanted an Amāvāsya or New Moon day to gratify the orthodox by presenting them with a general conjunction of the Sun, the Moon and the planets. Undaunted by the adverse result he made no scruple to carry back the origin of longitude itself seven degrees in order to show to the orthodox that the Mesha Sankrānti did fall on the New Moon day according to their expectations. To prevent this artifice from being detected it became necessary to distribute this increase of 7 days over 3600 years. He accordingly raised the length of the sidereal year given in the foregoing table 365 days 6h 9m 53s = 365 days, 15gh, 24pa, 42vip to 365 days 15 gh 31 pa 30 vip. Thus the vitiated sidereal year was introduced for the first time and was implicitly followed by the subsequent astronomers without the least suspicion. The equinox had receded three degrees behind Chitrā in Shaka 421 and the arbitrary putting back of the starting point by seven (7) degrees raised the error to ten (10) degrees or days in the Zero year of the Kalyuga. This minus error of 10 days or 36000 palas is made good at the annual rate of 7 pala, in about Kali 5000 years. So now A.D. 1920 is the proper time for rejecting the vitiated year and for replacing it by its modern correct value 365d 15gh 23p adopting the time honoured starting point opposite to the star Chitrā (Alpha Virginis).

The liberties taken by Āryaṇātha with the positions of the planets in bringing about a perfect conjunction on the 17/18 of February 3102 B.C. are really appalling. He has added empirically $+35^\circ$, $+33^\circ$, $+12^\circ$ — 17° , $+20^\circ$ to the longitudes of the planets beginning with Mercury with corresponding changes in their mean motions and has intentionally observed silence in the matter

* The supposed author of the original *Bṛaryā* Śr. Āryabhaṭa was probably his pupil at Kusumapura. For he says—आदर्शनस्तिवह विप्रवति सुवह परेऽवर्तिनं ज्ञानम् ।

of the latitudes and longitudes of the yoga-taras probably for fear of his artifice being detected from their observations

We shall now demonstrate below by making use of the data of our Jyotirganita how the sidereal year of the ancient Aryans was changed into that of the Surya Siddhanta —

Explanation.	In Kali	Abdapa or Vara	Yithu Shukla
Time of the Sun's arrival— At the Equinox of Shaka 218 Jyo p 64 In shaka year 1800 Spica—160	Year 4979	v gh pa 6 0 08	9 8"
Table 10 Change in years	4000 900 70 9	6 29 5" 3 44 13 3 56 46 4 18 28	29 86 28 17 24 37 9 56
Deduct from the top line the sum	4979	4 09 17	29 76
At Equinox of Shaka 218 Spica — 180°	0	3 40 11	10 06
Change for precession — 3°		—3 2 43	—3 10
At Equinox of Shaka 4°1 Spica — 183°	0	5 37 23	6 06
Arbitrary Set back for New Moon — 6 74		—6 48 12	—6 06
At Arbitrary starting point Spica — 189° 74	0	5 49 16	30 00

This arbitrary set back of 6 days 48 gh 12 palas made in the Abdapa for the sake of the New Moon of the preceding 3600 years amounts to 6 pa 48 vipalas per year and consequently

	days gh. pa vip
The Aryan year (adopted by Ptolemy through the Chaldeans)	365 15 24 42
Arbitrary increase	+ . 6 48
The Surya Siddhanta year	<u>365 15 31 30</u>

(d) Use — This ancient Indian civil calendar being cyclic is fixed and does not stand in need of annual calculations. Being also solar it is free from the uncertainty of the intercalary months. In practical use it can be used as a safe guide in the determination of the dates of ancient events. As an instance of this we have determined in Section 201 the date of the Mahabharata and the Bhagavadgita within very close and precise limits.

(c) Though entirely solar in character, the table also affords means of calculating the tithi and the nakshatra on a given day. They can be calculated by means of the following formulae

$$\text{Tithi} = 6 + 0.920742 M$$

Where M is the period, in solar months, expired between the beginning of the cycle in which the given date is included and the end of the given solar month

Example 1—Required the tithi on the day of the summer Solstice in B.C. 483. This day marks the end of the third solar month

The given date lies in the 3rd cycle, therefore

$$\begin{aligned} M &= (699 \text{ years} - 7 \text{ months}) - (483 \text{ years} - 3 \text{ months}) \\ &= (698 \text{ years} + 5 \text{ months}) - (482 \text{ years} + 9 \text{ months}) \\ &= (215 \text{ years} + 8 \text{ months}) = 2588 \text{ solar months} \end{aligned}$$

And the required

$$\text{Tithi} = 6 + (0.920742 \times 2588) = 18.88 = 19 \text{ nearly}$$

This means that the festival Vāśa of the Buddhists or the 'Fete de Soleil' of the French astronomers was held in B.C. 483 on the Sankashti day (*Vide Sec 98*) where this same tithi is 18.3 as worked by the *Sūrya Siddhanta* elements

The Nakshatra (N) can similarly be obtained by the following formula—

$$\begin{aligned} N &= 13.5 + (0.9 \times \text{tithi}) + \frac{1}{2} (\text{Sun}^\circ - \text{Spica}^\circ) \\ \text{On the day of the summer Solstice in B.C. 483 for example} \\ N &= 13.5 + (0.9 \times 19) + \frac{1}{2} (90^\circ - 170^\circ) \\ &= 13.5 + 17 + 21 = 51.5 = \text{Pūrva Bhādrapadā} \end{aligned}$$

Note—In order that the solar months may coincide with the English calendar months without affecting the years it is safer to add 90 degrees to the Sun's longitude in col. 6 of the table, and then to divide the sum by 360. The quotient will correctly express the calendar months. Or solar months may be counted from April as one

Example 2—Find the tithi on which the era of Nabonassar commenced it being known that the years in it begin when the Sun's longitude is 330 degrees. It commenced on February

26, 747 B. C. in the second cycle, which began with the Sun's longitude 180° . We must take it as 270° and the solar month as the 9th for the above reason.

As before,

$$\begin{aligned} M &= (946 y - 9 m) - (747 y - 2 m) \\ &= (945 y + 3 m) - (746 y + 10 m) \\ &= (198 y + 5 m) = 2381 \text{ solar months} \end{aligned}$$

And the required

$$\text{Tithi} = 6 + (.92 \times 2381) = 6.52 \text{ Saptami.}$$

(f) *Important note*—This calculation discloses the important fact that the Chaldean and the Egyptian Era of Nabonassar and the Indian Aryan Era began on a Saptami. Not only this but even the length of the sidereal year is the same in both the Eras. This cannot be accidental, and as the Indian Era precedes the Chaldean Era by more than four centuries, the Chaldeans must have in all probability borrowed from the Indian Aryans their Era and Chronology. After making use of it as a basis for their astronomical pursuits the Chaldeans have returned the debt to us in the form of their astronomy. Though it is not proper to indulge in mere speculations, yet I cannot forbear saying that an important truth lies hidden in the word Chaldean, for it seems closely allied to the Sanskrit word काल, Nay the Chaldeans themselves seem to have been a colony of the Indian Aryans calling themselves *Caldais*, i.e., Time-givers or Chronologers. There is historical evidence to show (see Chambers' Ancient History) that the Chaldeans, though much respected for their learning, were looked upon as foreigners in Mesopotamia. They might also have carried with them from India the memory (स्मृति) of the general conjunction of the planets that took place in B. C. 3102, and of the imaginary vast cyclic periods of 432000 years (*vide* Sec. 209).

(g) On page 273 of "Histoire Abrégée de L' Astronomie par E. Lebon, 1899" we read the following description about the Chaldeans: "Les Chaldéens ont précédé toutes les autres nations pour les observations astronomiques. D'après Diodore de Sicile, ils comptaient 432000 années d'observations astronomiques que

Berose réduit à 150000 ! Ces nombres sont de nulle valeur en histoire, cependant ils montrent la grande antiquité de ces observations. La date terminale de la Chaldée 538 av. J. C., est l'année de la prise de Babylone par Cyrus.

Mr R Shama Shastri of Mysore has very ably proved in his *Gavāmāyana* the relation between the Vedic word नराचसरा (Narashamsaswara) representing 43200 syllables and the Chaldean words nerus, sosus and sarus for the cycles of 600, 60 and 3600 years respectively. His book contains reliable and very interesting information regarding the dim antiquity of the Vedic times.

(3) THE CHINESE CALENDAR

153. The Chinese calendar is luni-solar the months being lunar and the years tropical. It is not based on any cycle but is computed like ours by means of the true positions of the Sun and the Moon. Their era commences in the year B. C. 2637, and is reckoned in cycles of 60 years like our Deccan Samvatsara Chakra. In the year A. D. 1919 seventy-five of such cycles had elapsed and the 56th year of the seventy-sixth cycle was current. The samvatsara in the Deccan in A. D. 1919 was the 53rd called Siddhārthi. This near approach of the numbers of the years in the cycle suggests the probability of a common origin of the Indian and Chinese chronology at some remote time.

The year begins in that lunar month in which the Sun's tropical longitude is 330°. At present the first month concurs with the Hindu lunar month of Māgha. The months are indicated by the ordinal numbers like the Hindu Tithis and not by the sidereal names like Chaitra, Vāishākha, etc. The Adhika or the intercalary month bears the same number as that of the proper one. Their week days are 60, and have the same names as the years have in the 60 year cycle. The day begins at midnight and is divided into 12 equal parts. Their almanacs are prepared from tables constructed in the year A. D. 1644 by Imperial order. But since the establishment of the Chinese Republic changes consistent with the calculations of the French *Connaissance des Temps* are said to have been introduced into them.

THE SAYANAVADIS

Note.—The Chinese Calendar is a true Sâyana Calendar. The Indian Sâyana^{vâdis} should, if they like, adopt it and stop in future their advocacy for giving the sidereal names to their lunar months and to their tropical 27 divisions of the Ecliptic. Seeing that the 12 zodiacal constellations no longer coincide with the 12 signs, European astronomers have long since abandoned the custom of stating the longitudes in signs, and have adopted in its place that of mentioning them in degrees (0 — 360). The constellations are only shown with vague boundaries in their star-atlases and are used in giving names to fixed stars.

The 27 nakshatras are the pure Indian zodiacal constellations used long before the adoption of the Assyrian 12 constellations. To name after them the 27 moveable (tropical) divisions of the ecliptic from the vernal equinox is, not only inconsistent, but productive of great confusion in future ages. There is no objection if the Sâyana^{vâdis} name their 27 divisions by the ordinal numbers just as the Chinese do their months. The word Sâyana-Nakshatra is in itself ludicrously inconsistent, as it literally means a moving-stationary division. Modern astronomers have, it appears, omitted the old word 'sign' in their tables in order to avoid this very objection.

(4) THE JEWISH CALENDAR

154. The calendar of the Jews is luni-solar and is regulated by a cycle of 19 years, called the Metonic cycle. Its months are lunar. The year contains 12 lunar months when it is common, and 13 months when embolismic. The years 3rd, 6th, 8th, 11th, 14th, 17th and the 19th in the cycle are embolismic or *adhika*. The order is nearly the same as that of the *adhika* years in Table 2. Deduct 1 from the years given in line 1 of it, and you obtain the above figures. But there can arise no *Kislay* months in a cyclic reckoning. It is produced only when the names of Lunar months are determined with reference to the Solar months. (Sec. 65.)

155. The names of months are of Assyrian origin. These are—1 Tisseri, 2 Herwan, 3 Kisler, 4 Tibeth, 5 Schebat, 6 Adar, 7 Ve'adar

(adhika), 8 Nissan, 9 Iyar, 10 Sewan, 11 Tamouz, 12 Ab, and 13 Eloul.

Like the Vedāṅg Jyotisha the intercalary month Ve'adar is placed in the middle of the embolismic year. The first month usually concurs with the Hindu Āshvina. The day begins at sunset as in the Musulman calendar. The year is not permitted to begin on a Wednesday, Friday or Sunday, but on the day following, as they are considered unlucky.

The Jewish Calendar was recast into its present form in the fourth century A. D.

(5) THE ECOLESIASTICAL OR CHURCH CALENDAR

156. Easter is the only religious festival, says Prof. Newcomb, which in Christian countries depends directly upon the motion of the Moon. The rule for determining Easter is that it is the Sunday following the first full Moon, which occurs on or after the 21st of March. The Church calculations of Easter Sunday are, however, founded upon very old tables of the Moon, so that if we fix it by the actual positions of the Moon, we should often find the Calendar feast a week in error.

"The natural units of time," says C. A. Young in his *Manual of Astronomy*, "are the day, month, and year. The day is too short for convenience in dealing with considerable periods, such as the life of man for instance, and the same is true even of the month, so that for all chronological purposes the tropical-year—the year of the seasons—has always been employed. At the same time, so many religious ideas and observations have been connected with the changes of the Moon that, there was a long constant struggle to reconcile the month with the year. Since the two are incommensurable, no really satisfactory solution is possible, and the modern calendar of civilized nations entirely disregards the Moon."

Use of the Golden number and of the Dominical letter

The Golden number and the Epact at the beginning of a year are useful in fixing the date of the Paschal full moon, and the Dominical letter serves to show the Sunday dates. The French

Annuaire for A D 1919 contains two tables which give the Easter days from A D 1600 to 2200, both according to the Old and the New Styles

157. Easter can be calculated by means of our tables also. At present the Meshadi occurs on the 12th of April. So the Easter full moon occurs between March (21—31) when the tithi-Shuddha lies between 27 and 7, and between April (1—20) when it lies between 7 and 27. The date of Meshadi increases by 1 in 60 years, so the limits of the tithi Shuddha will have to be raised by one when the Meshadi will occur on the 13th of April

Rule—Calculate the mean elements for the Meshadi of the given A D year according to Sec 77 and complete the tithi Shuddha or Epat as it is called, by Sec 78. Then deduct algebraically the completed tithi from 15, find out from Table 5 the motions of the elements for the remaining tithis and add them, according to the sign of the remaining tithis to the elements of the Epat

Calculate the ending moment by Sec 79-81. Then the date of the Sunday, next to the full-moon will be that of *Easter Sunday* and the preceding Friday will be Good Friday. If the full moon falls on a Sunday, Easter day is the Sunday after

Example—Determine the date and the week-day of the Easter full moon in A D 1920

Type of Calculation for Easter day

Explanation	A D	Tithi	Vāra	Date	☾ s anom	☉ s anom
Tab 3	1900	13 627	5 620	A 12 620	7° 4	280° 6
4	20	11 297	4 175	0 175	41 9	0 0
At Meshadi	1920	24 324	2 795	A 12 795	49 3	280 6
Complement		6 676	0 666	0 666	8 7	0 7
S		25*	3 461	A 13 461	58 0	281 3
Tab 5 R	nomes	10	2 844	9 844	128 6	9 7
T		15	0 617	A 3 617	289 4	271 6

Here Easter Full Moon falls on Saturday the 3rd of April. Easter, therefore, occurred on the 4th of April 1920

(6) THE COPTIC CALENDAR OF EGYPT

158 This calendar is used in parts of Egypt and Ethiopia. Like the calendar of the Persis the year consists of 12 months, each containing 30 days with 5 intercalary days called *Epagomenes* added at the end of the twelfth month. After three such years of 365 days in succession the fourth year has 6 epagomen days added at the end. Thus it will be seen that the length of the Coptic year and the intercalation are the same as in the Julian Calendar.

The intercalary or leap years of the Coptic calendar are those next preceding the Julian bissextile years. See Sec 144 Old style.

The era followed is that of the Diocletian or of the Martyrs, the origin of which is fixed on Friday 29th August 284 A. D.

Concordance of the Julian and Gregorian dates with the first day of each Coptic month in a common year (1837)

No	1837 Coptic months and their duration in days 2nd common year	1920 Julian dates and months	1920 Gregorian dates and months
1	Tut 1 days 30	29 August	11 September
2	Bobeh 1 30	28 September	11 October
3	Hatur 1 30	28 October	10 November
4	Koyhak 1 30	27 November	10 December
5	Tubeh 1 30	27 December 1921	9 January
6	Amchir 1 30	26 January	8 February
7	Barmahat 1 30	25 February	10 March
8	Barmudeh 1 30	27 March	9 April
9	Bachones 1 30	26 April	9 May
10	Bawne 1 30	26 May	8 June
11	Abib 1 30	25 June	8 July
12	Meson 1 30	25 July	7 August
	Epagomenes 5	24 August	6 September
1	Tut 1 1838 365	29 August	11 September

An intercalary Coptic year ends on the 29th of August instead of the 28th ; and the next Coptic common year, having to concur partly with a Julian bissextile year, ends on the 28th August of the bissextile year. The second common Coptic year again commences on the 29th August of the Julian year. The formula of Coptic Leap Year (C) is : $Q (C + 1) \div 4 = 0$.

The excess of the Gregorian dates over those of the Julian is at present (A. D. 1920) 13 days. It will be 14 days on the 20th date of February of the Julian calendar in A. D. 2100, and 15 days in A.D. 2200. (The above information about the Coptic calendar is derived from the French *Annuaire* for A. D. 1920.)

CHAPTER XV

ECLIPSES

Importance—Eclipses, when they are mentioned in inscriptions and copper plates, are an unerring means of verifying their dates. The Hindu Scriptures affirm that the merit of a gift, made on the occasion of an eclipse, is great and permanent. It was mainly owing to this religious faith that the kings and princes of India made free grants of lands and even of villages to deserving Brahmins on the occasion of important eclipses.

159. Possibility and recurrence.—A lunar eclipse can occur only at the time of Full Moon, and a solar eclipse only at the time of New Moon, if the Sun happen to be near enough to one of the nodes of the lunar orbit (*vide* Sec. 55). The Moon is eclipsed by the earth's shadow, and the sun is eclipsed by the dark opaque body of the Moon passing like a cloud between a spectator on the earth and the sun. The interval between two successive eclipses is generally six months and sometimes a fortnight.

160. The Saros.—The cycle of the eclipses is called 'Saros', a word probably allied to 'Saura' by which name the celebrated Sūrya Siddhānta is sometimes cited. It was known to the ancient Chaldeans who used it to predict eclipses. It consists of 223 lunations, or 18 years and 10 or 11 days. In this interval there occur 71 eclipses of which 43 are of the sun and 28 of the moon. Though

the number of the Sun's eclipses is larger, their visibility in respect to a given place on the earth is much limited by the fact that the earth's surface traversed by the moon's penumbra is much smaller than that of the earth's hemisphere. It may sometimes happen that a partial solar eclipse actually seen in the Punjab may not be seen at all in the Madras Presidency and *vice versa*.

161 Our object in including the subject of eclipses in this book is not only to enable our readers to become acquainted with the calculation of one of the most interesting and awe inspiring phenomena but to show the great merit of the *Surya Siddhānta* that has turned, as it were, the two luminaries into its most obedient servants during the past 50 centuries. Besides our readers will be able to verify doubtful cases of eclipses independently of the list supplied to them by others. (Sec. 218.) Also there are very few books in India on this subject accessible to the English knowing readers so that they will find this subject a good pastime to enjoy when an eclipse is approaching.

THE ECLIPSE OF THE MOON

162 Method of calculation.—Take down from Table J the first 7 elements for the last preceding century of the given date and go through all the successive steps as described in Sects 77—80 till you obtain the ending moment of the true full moon tithi.

If the date be modern the empirical corrections of the *Vara* date, and moon's anomaly $\pm + 0.014$ day $+ 0.014$ day and $+ 3^{\circ} 33'$ respectively must also be added after the increase for odd years. (Sec. 101.)

Example—Calculate the lunar eclipse that took place on the 15th tithi of Chaitra Shaka year 1896 corresponding to 10th April 1884.

Note—This eclipse is noteworthy for the fact that it was calculated with the elements of *Grahalaṅkāra* and was found to be invisible at Bagalkot. Great was the surprise and chagrin of the pious and orthodox people when they beheld the moon rise with her upper border immersed in the earth's shadow, lasting over a ghāṭi.

Type of calculation

Tables.	A D	Trith	Vara	Date	☿ s An	☽ s An	Rāhu
3 rd	1800	15 543	5 743	A 10 743	157 94	280° 60	70° 84
4	84	29 445	0 733	0 733	173 93	0 00	185 64
Corr			0 014	0 014	3 33		
Mesbada	1834	15 983	6 491	A 11 491	337 20	280 60	256 5
Complement		— 983	— 9 3	— 973	— 12 63	— 97	
S		15	5 571	A 10 571	324 33	279 63	256 5
6 Arg	979 6	0 eq	+ 176	+ 176	+ 2 11	+ 176	× 12 =
7 Arg	376 7	☿ eq	— 243	— 243	326 68		2 11
Full Moon		(f)	3 45 A 10 45	Thurs	27 gh	7 pal	

The above calculation shows that the Full Moon of Chaitra fell on 10th April 1834 at 27 gh 7 palas after the mean sunrise of Ujjain.

163 Then calculate D which denotes the distance of the sun from the node Rahu according to the following formul and add 180° to it when the eclipse is a lunar one

$$D = + \text{Rahu}$$

$$+ \text{☽ s anomaly}$$

$$+ \text{☽ s equation} \times 13$$

$$+ \text{☿ s equation}$$

$$+ 02^\circ (h-50) = \text{Empirical correction.}$$

$$h = \text{Centuries of Kaliyuga.}$$

Example—

$$D = 256 53 = \text{Rahu}$$

$$+ 279 63 = \text{Sun s anomaly}$$

$$+ 2 29 = \text{☽ s eqn} \times 13 = + 176 \times 13$$

$$- 0 25 = \text{☿ s eqn}$$

$$+ 0 00 = 02 (50-50) = \text{Empirical correction}$$

$$+ 180 00 \quad \text{To be added the eclipse being lunar}$$

$$\hline 358^\circ 20$$

164 With the value of D thus obtained, we are able to decide from the following limits whether a lunar eclipse will happen. . .

Lunar ecliptic limits. "

A lunar eclipse is	..	{ Doubtful | Certain or | Doubtful.
If D is between	..	{ $347^{\circ}-350^{\circ}$ | $350^{\circ}-10^{\circ}$ | $10^{\circ}-13'$
or D is between	..	{ $167^{\circ}-170^{\circ}$ | $170^{\circ}-193^{\circ}$ | $190^{\circ}-193'$

In the above example D is $358^{\circ}20'$ and lies between the limits $350^{\circ}-10^{\circ}$ of certainty. We are, therefore, able to assert that there *shall* be an eclipse of the moon on the day in question. But the question in respect of its visibility must be postponed till we calculate the times of the moon's first and last contacts with the earth's shadow. If either of these times falls that day, after sunset and before the next sunrise, the lunar eclipse is sure to be seen.

165 Next find out the values of the elements v , a , b , l , p , and t as shown below—

From Table,	With Argument	Take out,	Which is the —
25	ζ 's anomaly,	v	= Moon's true daily motion. .
26	v	a	= Sum of semi-diameters of the moon and earth's shadow
26	v	b	= Difference of the semi-diameters,
27	D	l	= Moon's latitude.
28	$(a-l)$, a ,	p	= Semi-duration of the eclipse
35	$(b-l)$, b ,	t	= Do. of the total phase

Note.—In a lunar eclipse l should always be considered plus in finding out p and t from tables 28 and 35.

Example.—Thus :—

From Table	With Argument	We get
25	$326^{\circ}66'$..	$v = 736'$ minutes.
26	$736'$..	$a = 55$ "
26	$738'$..	$b = 24$ "
27	$353^{\circ}20'$..	$l = -10$ "
28 . ..	$45'$ and $55'$..	$p = 282$ palas.
35	$14'$ and $24'$..	$t = 116$ palas.

166. The time of the Full Moon is not the time of the middle of the eclipse (m). The difference between these times depends upon D , and never exceeds 26 palas or about 10 minutes which can be ignored except when great accuracy is desired, in which case it may be found out in the following manner.

Deduct D algebraically from either 180° or 360° whichever be nearer to D . Then double the difference in degrees which will be the correction (c) in palas to be made to (f), the time of Full Moon, as shewn in the preceding type of calculation.

$$\text{So, } (f + c) = (m)$$

In the above example D is $358^\circ 20'$, and 360° being nearer to it, $360^\circ - 358^\circ 20' = +1^\circ 8'$. The double of $+1^\circ 8'$ is $+4$ which is the correction (c) in palas. This being plus, 27 gh. 7 pa. $+4$ pa. or 27 gh. 12 pa. is the time of the middle of the eclipse. (m)

167. The times of the different phases can afterwards be determined with the aid of the following formulæ.

$(m - p)$ = beginning of the eclipse.

$(m - f)$ = beginning of the total phase.

$(m + c)$ = middle of the eclipse.

$(m + f)$ = end of the total phase.

$(m + p)$ = end of the eclipse.

$(a - f)$ = magnitude of the eclipse.

$(b - f)$ = *Khagrāsa*, i.e., covering of the sky, or extent of shadow beyond the moon's disc.

The *magnitude* is usually expressed in digits. A digit is equal to 2.5 minutes of arc. The calculation of the different phases by the above formulæ is shown below.

Lunar Eclipse. April 10, 1684. Ujjain mean time.

Eclipse begins. $m - p$		Totality begins. $m - f$		Mid eclipse. $m + c$		Totality ends. $m + f$		Eclipse ends. $m + p$	
gh.	pa.	gh.	pa.	gh.	pa.	gh.	pa.	gh.	pa.
27	12	27	12	27	12	27	12	27	12
- 4	42	- 1	50	-	.	+ 1	50	+ 4	42
22	30	26	10	27	12	29	0	31	54

$(a - f) = (55 - 10) = 45$ or 18.0 digits of magnitude.

$(b - f) = (24 - 10) = 14$ or 5.6 digits of *Khagrāsa*.

168 The points of contact on the disc—The first contact with shadow in a lunar eclipse takes place on the eastern border of the moon's disc and the last contact on the western border. In the Solar eclipse the opposite of this takes place.

ANCIENT ECLIPSES

169 The most ancient lunar eclipse of 8th March B C 720.—This eclipse has been cited by Ptolemy as having been observed at Babylon in the latter half of the night the magnitude being three digits. This we will calculate below, to show to the readers that the highest praise and almost religious regard paid in India to the *Surya Siddhanta* is not undeserved. The longitude of Babylon from Ujjain is $31^{\circ} 3'$ West or — 09 day and the latitude $32^{\circ} 5'$ North. The indefiniteness of the time says Newcomb renders the eclipse of very little value. (Researches on the motion of the Moon, page 36.) According to his calculation the time of the greatest phase at Ujjain is 3 A M.

Model of calculation

Explanation	B C	Tithi	Vara	Date	☾ s anom	☉ s anom	—Rahu
Tab 3	—801	17 98	1 98	VI 6 98	110 9	280 6	138 9
4	80	15 19	2 70	0 70	167 6	0 0	108 2
4	1	11 06	1 26	0 26	92 1	0 0	19 3
Charitra	—720	14 23	5 94	VI 7 94	10 6	280 6	66 4
Longt. of Babylon			— 09	— 09			
Mesbādi		14 23	5 85	VI 7 85	10 6	280 6	266 4
Complement		77	76	76	9 9	0 8	0 0
Mean tithi		15 00	6 61	VI 8 61	20 5	281 4	266 4
Tab 6 ☉ s eq Arg	281°		+ 17	+ 0 17	2 0	= 10 17	× 17)
Tab 7 ☾ s eq Arg	22°		+ 17	+ 0 17	22 5		
Mid Eclipse on			6 95	VI 8 95	Friday	4 48	A M

We must first calculate the value of D by Sec 163

D = 266 40 Rahu

281 40 ☉ s anomaly

2 21 ☉ s eqn × 13 = 17 + 13

0 17 ☾ s equation

—C 54 02 (23 — 50) Empa Corr

180 00 The eclipse being lunar

9 64

By Sec 165 we find the following values of α , l and p

Table 25 Arg ϵ s anom $22^\circ 5$	$v =$	730 0
26 Arg $v = 730$	$\alpha =$	55 2
27 Arg $D = 9^\circ 6$	$l =$	49 0
Magnitude $= (\alpha - l) = (55 - 49)$	$=$	6 2
Magnitude in digits $= 6 \cdot 2 \times 4$	$=$	2 5
Table 28 Arg $(\alpha - l)$ (α)	$p =$	130 0
semi duration in minutes	$=$	52 0

By Sec 167 $(m - p) = 4h 48m - 52m$
 $= 3h 56m$ Ecl begins
 $(m + p) = 4h 48m + 52m$
 $= 5h 40m$ Ecl ends

Example 2.—Calculate the Lunar Eclipse of September 1, B C 720. The magnitude was 6 digits. It was observed at Babylon and is quoted by Ptolemy.

We shall make use of the elements of the preceding example and add to them the increase for the interval of 180 years from Table 5.

Prof Newcomb estimates the middle time for Uppan as 9 P M

Calculation

Explanation	B C	Tib	Vara	Date	ϵ s anom	\odot s anom	—Rahu
Table 5	—720	15	6 61	11 8 61	20 ^h 3	281 ^h 4	286 4
5		100	0 43	38 43	206 1	97 0	5 2
5		80	1 75	78 75	308 8	77 6	4 2
Ashv n		190 ^h	1 79	180 79	170 4	96 0	275 8
6 Arg $46^\circ \odot$ s eqn			— 18	— 18	— 2	— 18	$\times 12$
7 Arg $173^\circ \epsilon$ s eqn			+ 04	+ 04	173 2		
11 September 0			1 65	180 65			
September 1			1 65	1 65	= 9h	36 m	P M

Here $D = 275^\circ 8$ Rahu

$$\begin{aligned}
 & 96 0 \odot \text{ s anom} \\
 & - 2 3 \odot \text{ s eqn} \times 13 = 18 \times 13 \\
 & + 0 0 \epsilon \text{ s eqn} \\
 & = 0 5 02 (23 - 50) \text{ From corr} \\
 & 180 0 \text{ The eclipse being lunar}
 \end{aligned}$$

Tab 27 Arg $189 0 l = -45 0 \epsilon$ s latitude south

Tab 25 Arg $173^\circ 2$ $v = 807 \epsilon$

Tab 26 Arg 857 $\alpha = 61 2$

Magnitude $(\alpha - l)$ $= 16 2 = 6 \cdot 5$ digits.

Thus the preceding calculations confirm Ptolemy's statements as regards the magnitude of the lunar eclipse that happened 23 centuries ago, though we cannot vouch for the times which *are themselves* not precisely stated.

THE ECLIPSE OF THE SUN

170 Method.—Calculate as before the ending moment of the true New Moon, according to Secs 77 80 and then add the correction in time for the difference of longitude of the given place from the meridian of Ujjain.

171 Calculate D as stated in Sec 163 and determine with it by means of the following limits the possibility or certainty of the eclipse at least somewhere on the earth's surface.

Solar ecliptic limits

A Solar eclipse is	Doubtful	Certain	Doubtful
If D lies between	341° — 347°	347° — 13°	13 — 19°
or „	161 — 167	167 — 193	193 — 199

172 To be able to say definitely whether a solar eclipse will be seen at a given place, the following 12 elements are necessary. Of them the first four elements are obtainable from tables and the rest must be calculated.

Elements

- (a) Latitude and longitude of the place
- (b) Latitude of the Moon, by D (Table 27).
- (c) Diameter of the Moon, by ϵ 's anomaly (Table 25)
- (d) Diameter of the Sun, by \odot 's anomaly (Table annexed to Sec. 174)
- (e) The approximate ghati of the apparent or local middle (M) of the eclipse, Arg. ghati of Amānta (New-moon), Table 29.
- (f) The sun's tropical longitude by Sec. 173.
- (g) Sidereal time T at apparent middle of the eclipse, by Sec. 174

- (b) The *Natus* s , the parallax in the latitude of the Moon
Table 30 Arg T and latitude of the place
- (c) The Moon's apparent latitude which is = (Moon's
latitude $-$ *Natus*) = $(b + k)$
- (k) Sum of semi-diameters of the Sun and the Moon =
 $\frac{1}{2}(c + d)$
- (l) The Sun will be eclipsed at the given place if (c) is
smaller than (k)
- (m) The magnitude of the eclipse is equal to the
remainder of $(k - c)$

173. The tropical longitude of the Sun (f) at the moment of the true New Moon can be calculated by the following formula

$$\begin{aligned}
 (f) = \text{Tropical } \odot^{\circ} &= \odot \text{ s anomaly} \\
 &+ 77^{\circ} 3' \odot \text{ s apogee} \\
 &+ \odot \text{ s equation} \\
 &+ \odot \text{ s eqn } \times 13 \\
 &\pm \text{Precession of equinox. Tab 3}
 \end{aligned}$$

174 The sidereal time T at the time of the apparent middle of the eclipse, can be calculated by dividing by 6 the degrees of the sun's tropical longitude and adding the quotient to N the ghats of the apparent middle of the eclipse T is one of the arguments of Table 30 for finding out the *Natus*.

$$T = \frac{\text{Trop } \odot \text{ in degrees}}{6} + N$$

Table—Sun's diameter in minutes of arc.

Argument {	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
⊙ s anom.	360	310	270	300	280	260	240	220	200	180
⊙ s diameter	31.5	31.5	31.6	31.8	31.9	32.1	32.3	32.4	32.5	32.6

The Total Solar Eclipse observed at Nineveh

175. Example—We shall here calculate the great Eclipse of the Sun observed at Nineveh on 15th June B.C. 763 in the

Hebrew month of Sivan. The latitude of Nineveh is $36^{\circ} 3'$ North and its longitude is $31^{\circ} 5'$ West from Ujjain or $-0^{\circ} 09'$ day

Model of calculation by Secs 77-80

Table	B C	Tithi	Vāra	Date	ζ s anom	\odot s anom	Preces- sion	Rahu
3	801	17 98	1 98	M 6 98	110° 8'	280° 6'	-21° 07'	120 0
4	36	8 53	3 31	0 31	75 4	0 0	0 0	386 7
4	2	22 13	2 50	0 52	184 2	0 0	0 0	35 7
Long of Nineveh		18 44	0 81	M 7 81	10 5	280 6	21° 1'	154° 3'
			- 09	- 09				
At Nineveh Compl		18 44	0 72	M 7 72	10 5	280 6	-21° 0'	154 3
		56	35	55	7° 1'	0 5	0 0	0 0
S		19	1 27	M 8 27	17 6	281 1	-21° 1'	154 3
S R		100	0 43	98 43	206 1	07 0	0 0	5 2
S R		1	° 09	98	12 9	1 0	0° 0	0 0
T Asi Jdha 30		120	2 68	107 58	236 6	19 1	-21 1	109 5
6 Arg $19^{\circ} \odot$ s eqn			- 06	- 06	- 0 7	(-0 06 × 12)		- 7
7 Arg $236^{\circ} \zeta$ s eqn			- 33	- 33	235 9			
11 March 0 to June 0			2 ° 9	107 29				
				92 00				
		June	Mon	15 29	° 9 ×	60 =	17 4	ghatis

From Table 29 Arg 17 4 gh we get $M = 19$ gh of Mid-eclipse

Let us first calculate D by Sec 163 the Sun's tropical longi-
tude by Sec 173 and T by Sec 174

$$D = 159 \text{ } 5 \text{ Rahu}$$

$$19 \text{ } 1 \text{ Sun's anomaly}$$

$$-0 \text{ } 8 \text{ Sun's eqn} \times 13 = -06 \times 13$$

$$-0 \text{ } 3 \text{ Moon's eqn}$$

$$-0 \text{ } 5 \text{ } 02 (23 - 50) \text{ Emp corr}$$

$$\hline 177 \text{ } 0$$

By Secs. 173, 174.

Trop. $\odot = 19^{\circ} \cdot 1$ Sun's anomaly, as above.

77.3 Sun's apogee, constant.

— 0.8 Sun's equation $\times 13 = 10.6 \times 13.$

— 0.3 Moon's equation.

— 21.1 Precession, Ayanāmsa. Tabs. 3, 4.

$$(f) = \frac{74.6}{6}$$

$$1 = \frac{74.6}{6} + 17;4 = 29.8 \text{ ghatis.}$$

We shall now proceed to calculate in succession all the elements from (a) to (m) described in Sec. 172.

Elements of the eclipse, at 19 ghatis at Nineveh.

(a) Latitude of Nineveh.. .. .	N.	36°·8
(b) ϵ 's latitude, Tab. 27 Arg. $D = 177.0$.. .	N.	15'·1
(c) ϵ 's diameter Tab. 25 Arg. ϵ 's anom. 238 0		32'·0
(d) \odot 's diameter, Sec. 174 Arg. \odot 's Anom. 19°		31'·5
(e) Ghati of Mid-eclipse Tab. 29, Arg. $M = 17.4$ gh.		19'·0
(f) \odot 's trop. longitude as above calculated .. .		74'·9
(g) Sidereal time T, as above calculated .. gh.		29'·8
(h) Nati, Tab. 30, Arg. T and (a)	—	13'·3
(i) ϵ 's apparent latitude = $(b + h)$		1'·8
(k) Sum of semi-diameters of \odot and $\epsilon = \frac{1}{2} (c + d)$		31'·7
(l) Here j is smaller than k . Therefore the eclipse did take place at Nineveh.		
(m) The greatest magnitude was $k - j = 30'$ or 12 digits		30·0

It was a great solar eclipse. It passed centrally about 100 miles north of Nineveh. The diameter of the Moon being greater than that of the sun it was total and was, therefore, placed on record by the Assyrians of Nineveh.

The moments of first and last contact may be accurately computed by means of the author's *Ketali* or *Jyotiṛganita*.

The great Solar Eclipse observed at Babylon

176. As a second Example, we will calculate below the great solar Eclipse observed at Babylon on July 31, 1063 B. C.

Elements of the Solar Eclipse seen at Babylon.

(Babylon meantime)

Monday, July 31, B C 1063

(a) Latitude of Babylon	.. .. N	32°·5
(b) ϵ 's latitude Tab 27 Arg D.	.. .. N.	6°·4
(c) ϵ 's diameter, Tab 25 Arg ϵ 's anom	242 4	32' 0
(d) \odot 's diameter, Sec 174 Arg \odot 's anom,	67°	31'·8
(e) M time of middle of Eclipse	.. .. gh	9·6
(f) \odot 's tropical longitude	.. ..	116°·5
(g) T Sidereal Time at Mid-eclipse	.. .. gh	29 0
(h) Natl, Tab 30, Arg T and Lat	32 5	—9°·5
(j) ϵ 's apparent latitude = $(b + h)$	.. ..	—3' 1
(k) Sum of Semi-diameters of \odot and ϵ =		
$\frac{1}{2} (c + d)$	.. ..	—31' 9
(l) $j < k$ Therefore eclipse was visible at		
Babylon		
(m) the magnitude was $(k - j) =$		23'·8
or $23 \cdot 8 \times \cdot 4 = 11 \cdot 5$ digits		

Note—In finding the magnitude the sign of (j) should be considered to be plus always

The eclipse was nearly as large as that observed at Nineveh on June 15, 763 B C But in the present instance the central line of the Moon's shadow must have passed $-3' 1 \times 70 =$ about 200 miles to the south of Babylon

The diameter of the sun being smaller than that of the moon the eclipse was total on the central line

CHAPTER XVI

Time

177 Time is simply an idea inseparably connected with the idea of motion or action So that both being concurrent, either of them can be considered as the measure of the other The year, month, day, hour, &c. measure, in the astronomical calculations, the

motion of the heavenly bodies, and conversely the motion of the heavenly bodies such as the Sun, the Moon and the planets is used in chronological calculations to measure time.

Smaller actions or motions are employed to measure smaller divisions of time. The pulsations were employed to measure time in India long before the time of Galileo. This is shewn by the fact that the celestial Equator is called *Nādi Mandala* in all the ancient *Siddhāntas*. *Nādi Mandala* literally means the pulsation circle. In common parlance the smallest portion of time is expressed by the phrase 'the twinkling of an eye'. On the other hand distance is often expressed by the time taken to go over it. The vast stellar distances are expressed in astronomy by light years. Light travels at the inconceivable rate of 186,000 miles per second.

178 Before the invention of clocks and watches, the *Ghatis*, *lāpāira*, the clepsydra and the sundial were employed to measure time, which generally commenced at sunrise noon, or sunset. The time obtained from them was of course rather too rough to be used in accurate observations. The invention of chronometers served to give the greatest stimulus to the progress of astronomy. But finding that chronometers were incapable of following the capricious movements of the Sun modern astronomers have called in the help of a fictitious point called the mean sun in the *Siddhāntas* which is supposed to move always with uniform motion along the celestial equator. The astronomers know the exact interval by which the mean fictitious sun arrives at the meridian, either before or after the shining Sun. This interval is called the *equation of time*. It is therefore necessary to observe every day the meridian passage of the real Sun and to set the chronometers so as to show the position of the mean sun. An observatory is therefore indispensable if civil and public affairs are to be conducted in accordance with mean time. With this object in view western nations have built observatories at or near their capitals, from which correct mean time is every day wired to all the important places connected by railways and telegraphs. Lately mean time is communicated to steamers

at sea by means of wireless telegraphy, it being formerly obtained by the observation of lunar distances.

179. The time hitherto shown in the Tables and calculations is the *mean solar time of Ujjain (U. M. T.)*. The meridian that passes through the old Observatory of Ujjain is used as the origin of longitude by all the Siddhāntas. Ujjain is, therefore, the Greenwich of India. Its longitude is $75^{\circ}46' \cdot 1$ East of Greenwich and its latitude is 23° North.

Ujjain seems to owe this honour chiefly to its central position and to the fact that it was once the capital of one of the most powerful and enlightened King called Vikrama, whose era still prevails over the greater part of Northern India. He liberally patronized arts and sciences, and invited many learned men to his court.

180. The Indian Standard Time,—It is 5 hrs. 30 m. and 27 m. in advance of the Greenwich and Ujjain mean times respectively, and 2 minutes behind the Benares time. But mean times are not to be used in the performance of Hindu religious ceremonies. All the statements of time for this must be made in the Sāvāna Time (*vide* Sec. 64) which is measured from the moment of the actual sunrise at the given place. For this purpose the Ghatikāpatra is used and its immersions in water are watched and noted with little vertical lines of kumkuma on the white background of a wall. The watchman (a Joshi) is afterwards paid his fee and thanked for his trouble and is invited to dine at the festival.

181. To convert meantime of Ujjain into Sāvāna time of a given place. (*Vide* Sec. 64)

We need calculate only the two arguments, (a) and (b), to obtain the three corrections from one and the same Table 33. The latitude and the time difference of longitude from Ujjain can be obtained from maps or other sources, such as my Jyotirganita.

(a) The tropical longitude of the sun.

(b) The Sun's anomaly.

(c) The equinoctial shadow at a place can be obtained from Table 34, when its latitude is known.

To convert Ujjain meantime into sāvana time

THERE ARE TWO CASES:

First, when the given date is Luni-Solar

182 In the case of a luni-solar date the sun's anomaly becomes available in the course of its computation. But the sun's tropical longitude must be calculated by the formula of Sec. 173

Method—(a) From Table 33, with the sun's tropical longitude take out the palas and multiply them by the digits of the equinoctial Shadow of the place. The product will be the palas called *Chara*

(b) With double the number of the Sun's tropical longitude as argument, take out from the same table the palas and increase them by their seventh part and call them *Udayāntara*

(c) With the sun's anomaly as third argument, take out from the same table the palas and call them *Bhujāntara*

(d) The *Rekhāntara* should be reckoned at 10 palas per degree of longitude measured from Ujjain, and is plus or minus according as the place lies to the east or west of the meridian of Ujjain

(e) Add the above four quantities to the mean time of Ujjain according to their signs, and the sum will be the *Sāvana Time* of the occurrence of the phenomenon at the given place

$$\begin{aligned} \text{Sāvana Time} = & \text{Ujjain mean time,} \\ & + \text{Chara} \\ & + \text{Udayāntara,} \\ & + \text{Bhujāntara,} \\ & + \text{Rekhāntara} \end{aligned}$$

Example.—Calculate the *Sāvana Time* of the end of Ashāḍha Shukla 12, Thursday, *Shaka* 406, at Eran. Lat 24° N and Long 2 53' to the East of Ujjain. The tithi ended at 51 gḥ. 11 pa (U M T)

This same tithi has been worked out in Sec. 94, where the Sun's anomaly is 14° 5'. Table 34 gives 5·34 digits for the equinoctial shadow for latitude 24° N

We have now to calculate **only** the Sun's tropical longitude by Sec. 173.

Thus—

$$\begin{array}{rcl}
 \text{Trop. } \odot & = & 14^{\circ}5 \text{ Sun's anomaly,} \\
 & 77^{\circ}3 & \text{,, apogee,} \\
 & -0^{\circ}8 & \text{,, Eqn. } \times 13 = -0^{\circ}046 \times 13 \\
 & +0^{\circ}4 & \text{,, 's Equation.} \\
 & -0^{\circ}6 & \text{,, Precession for Shaka 406, Tabs.} \\
 & & 3, 4. \\
 \hline
 & & 90^{\circ}8
 \end{array}$$

With this preparation we can calculate the Sāvana time by Table 33, as follows :—

	gh.	pa.
Ujjain Mean Time	51	11.0
(Arg. 91°) for Chara; $20^{\circ}7 \text{ pal.} \times 5.34 =$.. + 1		50.5
(Arg. 182°) for Udayāntara; $-0^{\circ}65 \times 8 \div 7 =$.. - 0		0.7
(Arg. 14°5) for Bhujāntara + 0		4.8
Rekhāntara + $2^{\circ}53 \times 10 =$ + 0		25.3
Sāvana time at Eraṇ	53	29.9

2ndly, When the given date is Solar.

183 In the case of solar dates which are used in Bengal, Orissa, Tamil and Malayālam provinces, the arguments of Table 33 can be obtained by the following two formulæ.

$$\begin{array}{l}
 \text{Trop. } \odot = + \text{Longitude of Sankrānti in Tables 13, 15 or 17,} \\
 \quad + \text{Date of Solar month.} \\
 \quad + \text{Precession, Tables 3, 4.} \\
 \text{Sun's anomaly} = \text{Trop. } \odot, \text{ as obtained above.} \\
 \quad + 282^{\circ}7 = (360 - 77^{\circ}3). \\
 \quad - \text{Precession, by Tables 3, 4}
 \end{array}$$

Note —The remaining procedure is exactly the same as given in Sec. 182.

184. Time of Sunrise, Noon and Sunset.—The three corrections Chara, Udayāntara, and Bhujāntara, calculated in Sec. 182, can also be employed in solving problems of sunrise, noon, and sunset in local time, as shown in the following formulæ.

Let C, U, and B, the initial letters, denote the three corrections in palas and, let (*m*) represent the factor 0·4 for changing them into minutes of time. (Sec. 64 Note.)

Formulæ.—

- (a), Half day time = $6h. - m C$
- (b), Sunrise = $6h. - m (C + U + B)$
- (c), Noon = Sunrise + Half day time
- (d), Sunset = Noon + Half day time
- (e), Equation of time = $- m (U + B)$

Note.—The time of sunrise obtained by the above formula must be lessened by 2 minutes, and the time of sunset must be increased by 2 minutes for the retraction of the Sun's rays at the horizon. For greater accuracy the 2 minutes must be multiplied by the secant of the latitude of the place

(1) When the given date is Luni-Solar

Example—Calculate the mean local time of the above phenomena at Eran, Lat. 24 N., on Ashāḍha Shukla 12, of Shaka year 400

We make use of the corrections already computed in Section 182, viz., Chara + 110 pa., Udayāntara — 1 pa., and Bhujāntara + 25 pa.

Local mean time.

- (a), Half daytime = $6h. - 4 \times 110$
= $6h. 44$ minutes.
- (b), Sunrise = $6h. - 4 (110 - 1 + 5)$.
= $6h. - 46$ minutes.
= $5h. 14 m$ (A. M.)
- (c), Noon = $5h. 14 m + 6h. 44 m$.
= $11h. 58 m$ (A. M.)

$$\begin{aligned}
 (d) \text{ Sunset} &= 11^h 53^m + 6^h 44^m \\
 &= 6^h 42^m \text{ (P M)}
 \end{aligned}$$

$$\begin{aligned}
 (e) \text{ Equation of time} &= -4 \text{ } (-1 + 5) \\
 &= -1 \text{ 6 minutes}
 \end{aligned}$$

185. (2) When the date is Solar, we should calculate the arguments the sun's tropical longitude and anomaly according to Sec 183

We shall work out an example involving the highest latitude in India given in D B Pillai's Chronology page 27

Example 2—Find the time of sunrise at Shrinagar Lat 34° North, on the 4th date of the Bengal Solar month Margashirsha in the Kaliyuga year 4325

Here by Table 34 the equinoctial shadow for latitude 34° is 8 1 digits

By Sec 183—

Trop $\odot = 210^\circ 0$ longitude of the sun Tab 13 on the first day of Margashirsha.

$$\begin{array}{r}
 4 \ 0 \text{ The date of Margashirsha} \\
 11 \ 0 \text{ Precession Tab 3 K 1 } 4301 \\
 0 \ 4 \qquad \qquad \qquad 4 \qquad \qquad \qquad 24 \\
 \hline
 225 \ 4 \qquad \qquad \qquad 4325 \\
 \hline
 \text{s anomaly} = 225^\circ 4 \ \odot \text{ s tropical longitude,} \\
 282 \ 7 = (360^\circ - 77^\circ \ 3) \\
 -11 \ 4 \text{ Precession Tabs 3 4} \\
 \hline
 136 \ 7
 \end{array}$$

Tab 33 —

Arg $225 \ 4$ for Chara $(-14 \ 1 \times 8 \ 1) -$	Palasi — 114 2
90 8 for Udayantara $(20 \ 7 \times 8 - 7) =$	+ 23 7
136 7 for Bhujantara	+ 14 2

Correction to be made to 6 hours A.M	— 76 3
Correction calculated by D B Pillai	— 75 0
Correction calculated by Prof Jacob	— 74 0

By Sec. 184 eqn (b), $6^h - 4 (-76\ 3)$ minutes
 Sunrise = $6^h\ 30\cdot5^m$ (A.M.)

186 The Ishṭakāla and Lagna—Owing to the apparent diurnal revolution of the heavens, all the degrees of the Ecliptic rise in succession upon the horizon of every place on the earth situated within 66° of Latitude. In astrology the whole of the ecliptic is divided into 108 divisions called Navamāṁshas or quarter nakshatras, each of which is presided over by a particular planet, the qualities of which are supposed to influence the actions at the place, during the time which the Navamāṁsha takes to rise fully above the horizon, and which usually lasts about 33 palas.

The properties of the Navamāṁsha during which a child happens to be born are supposed to influence all its actions through life, although they are liable to modifications according to the effects of the aspects of the planets situated at different distances from the Navamāṁsha. It is the pivot on which the horoscope of an individual is made to turn and consequently its knowledge, correct to within a degree at least is essential to the astrologers.

In the performance of any important business, the time of the rising of inauspicious Navamāṁshas is to be avoided as far as possible.

Hence arise the following two problems

187 Problem 1—Given the Sun's sidereal longitude at sunrise, the auspicious degree of the Ecliptic (Lagna) and the latitude of the place, to find at what ghaṭi of the Sāvana time (Ishṭakāla) after sunrise, the auspicious degree of the Ecliptic will come in contact with the horizon.

Rule—From Tables 3 and 4 take out the precessional degrees and deduct from them $22\ 50$ algebraically and call the difference C , which is the correction for the precession.

Add C to the Sun's longitude S , and to the lagna L , and call the sums $(S + C)$ and $(L + C)$.

From Table 36, with arguments, latitude and $(S + C)$, take out sidereal time in ghaṭis entered in the first column of the table.

Again from table 36 with arguments latitude and $(L + C)$ take out the sidereal time

Deduct the former sidereal time from the latter. Then again deduct from the remainder as many Asus as there are ghatis in it six Asus being equal to one pala.

The result will be the *Ishtakala* or the desired Savana Time

Example—At how many ghatis and pala after sunrise was the 16th degree of the ecliptic in touch with the horizon (lagna) on the 6th day of the Bengal Solar month Jyestha in Kaliyuga year 4000 in Latitude 20° N at Puri in Orissa.

Tables 3 and 4 gave 6° 1' for the *Ayanāṁsha* in Kali 4000. Therefore $(6° 1' - 22° 5') = -16° 4' = C$

Table 13 yields $(30° + 5°) = 35°$ for the longitude of the Sun on the 6th day of Jyestha

	Sun	Lagna
Longitudes of	35 0	165 0
Precessional correction C	- 16 4	- 16 4
	<hr/>	<hr/>
Arg of Tab 36	18 6	148 6
	<hr/>	<hr/>
	Sidereal time of rising of—	
	Sun	Lagna
	gh pa.	gh pa.
Table 36 Arg Lat 20 and 18 6	5 30	0 0
Table 36 Arg Lat 20 and 148 6		23 25
Deduct	5 30	5 30
	<hr/>	<hr/>
Duration in sidereal time	0 0	22 55
Deduct 23 asus = 4 pala		- 4
		<hr/>
Result — The Savana time when 165 0 was Lagna		22 51
By D. B. Pillai's Chron. box page 30		22 52
		<hr/>

188 Problem 2.—Given the Sun's longitude, the *Ishtakala* or Savana time and the latitude of the place to calculate the Lagna or the rising degree of the Ecliptic

Rule.—Calculate the Sun's sidereal time of rising as in problem 1. Add to this the *Ishtakala* and as many *Asus* as there are *ghatis* in it.

With this sum as argument of Table 36 and under the given latitude in it, calculate the *Lagna* and add *C* to it with its sign reversed. The result will be the *Lagna* sought.

Example 2.—What degree of the Ecliptic was *Lagna* or rising at the same place and date at the end of the 20th *ghati*?

The sidereal time at sunrise is in the above example 5 gh. 30 pa. Thus increased by the *Ishtakala*, 20 gh. and as many *asus* (20 = 3 *palas*) amounts to 25 gh. 33 pa. as the sidereal time which is the Vertical Argument of Table 36. Opposite to this and under 20° of latitude we get for *Lagna* 132° 5'. Adding to this *C* with its sign reversed viz., 16° 4' we get for the *Lagna* or the rising degree of the Ecliptic 148° 9'.

<i>Type of calculation</i>	gh pa
Sidereal time at sunrise as before	5 30
Add the <i>Ishtakala</i> 20 gh	20 0
Add 20 <i>asus</i> = 3 <i>palas</i>	0 3
Sidereal time at 20 gh. Savana time	25 33
	<i>Lagna</i>
Tab. 36 Arg. 25 gh 33 pa and 20° lat	132° 5'
Add <i>C</i> —16° 4' with its sign changed	+ 16 4
Result —The <i>Lagna</i> at 20 gh.	. 148 9
Result reached by D. B. Pilla. and Prof. Jacobi	. 149 0

CHAPTER XVII

MISCELLANEOUS NOTES

In this chapter we mean to add for advanced readers a few notes on questions relating to theory, explanation, comment and antiquary.

NOTE 1

189 The beginning of Kaliyuga.—According to the *Sūrya Siddhānta*, the Kaliyuga which is a cycle of 432000 years, commenced at mid night of Lankā on Thursday, the 17 75th-of February 3102 B C. This means that the first point of Ashvin on the Ecliptic, the mean sun, and the mean moon, reached simultaneously the lower meridian of Lankā an imaginary spot on the Equator on the meridian of Ujjain. The *Siddhānta* further states that at this moment the longitudes of the apogees of the Sun and the Moon were $77^{\circ} 26'$ and 90° respectively.

190 But as the functions of civil life depend upon the true positions of the sun the almanac-makers seem to have rejected the mean zero moment of the zero year of the Kaliyuga and to have adopted in its place, for convenience's sake, that moment for zero, at which the centre of the true sun arrived at the first point, of Ashvin usually called Ashvinayadi.

This *True Epoch* of chronology, when calculated with the elements of the *Sūrya Siddhānta*, precedes the midnight of Lankā by 2 1707 days. It, therefore, occurred on the 17 75 — 2 1707 = 15 5793th day of February 3102 B C. At this moment the mean longitude of the Sun was $357^{\circ} 862'$ and the equation of its centre was $+ 2^{\circ} 138'$.

191 The *Abargana* or the days elapsed from the *Mean Epoch* of Kaliyuga, i.e., from 17 75th of February, 3102 B C., is often required in the planetary computations of the *Sūrya Siddhānta*. It is easily obtained by multiplying the days of the Solar year 365 258756484 by the number of years elapsed upto the Meshādi of any given year, and deducting from the product the constant number, 2 1707 days. This constant number is called *Shodhyā*, meaning a subtrahend. It has no application in chronology.

NOTE 2

192. Transformation of the chronological elements into Astronomical ones.—This is sometimes necessary for the purpose

of comparison with the latter, when available from an independent source. The transformation can be easily effected by means of the following formulæ.

The apogee of the Sun is supposed to be motionless. Its longitude is, therefore, always $77^{\circ} 26'$ from the first point of Ashvini.

Let S, M, A and N denote the mean longitudes of the Sun, the Moon, the Moon's Apogee and Node (Rāhu).

Then—

$$S = 77^{\circ} 26' + \text{Sun's anomaly}$$

$$M = S + (\text{titlu} \times 12)$$

$$A = M - \text{Moon's anomaly}$$

$$N = 77^{\circ} 26' - (\text{Rāhu}) \quad \dots \text{given in Table 3}$$

Example.—We shall calculate the values of S, M, A and N for the moment of the true epoch of Kaliyuga, the year of Table 3.

[Putting the chronological elements in their proper places in the preceding formulæ and solving them, we have—

$$S = 77^{\circ} 26' + 280^{\circ} 60' = 357^{\circ} 86' \quad \dots \text{☉'s longitude.}$$

$$M = 357^{\circ} 86' + (27^{\circ} 795' \times 12) = 331^{\circ} 40' \quad \dots \text{☾'s longitude.}$$

$$A = 331^{\circ} 40' - 241^{\circ} 57' = 89^{\circ} 83' \quad \dots \text{☾'s apogee.}$$

$$N = 77^{\circ} 26' - 235^{\circ} 18' = 202^{\circ} 08' \quad \dots \text{☾'s node.}$$

NOTE 3

193 Method of testing the accuracy of the consecutive and equidistant *mean elements* given in Tables 3, 4, 5, 14, 16, 18, 20 and 23, and of finding out a new one, that is not given in them. The elements affected by *Bija* or by abrupt changes due to the introduction of the Gregorian Style are exceptions. The accuracy of the figures of the remaining tables which are mostly sine-functions, may be examined by taking their first and second differences which ought to rise or fall uniformly without a hitch if they are correct.

If A, B C be any consecutive and equidistant mean quantities then they must satisfy the following equations —

$$2B = A + C$$

$$A = 2B - C$$

$$C = 2B - A$$

Example 1 — Suppose we want to test the accuracy of Samvat 36 112 for Kaly year 3001 given in Table 20 Part A we should proceed thus —

Kaly	Samvat	2 B	A + C
3001 A	36 112	39 622	36 112
3301 B	39 622	39 622	43 132
3601 C	43 132	19 244 = 19 244	

Here the first equation is satisfied Therefore the quantity 36 112 is correct

Example 2 — Suppose we want to know the Samvat for Kaly year 2601 which is not given in Table 20 We can obtain it in the following way —

Kaly Yuga	Samvat
2601 A	unknown
3201 B =	58 452
3801 C =	5 472

$$A = 2B - C = 56 904 - 5 472 = 51 432 \text{ Ans}$$

Example 3 — Suppose we intend to examine the accuracy of the figures in the 2nd column of Table 6 which vary as the sine of the suns anomaly We should do it thus —

Argument—		6	12	18	24	30	36°
Figures—	0	19		56	74	90	106
1st diff		19	19	18	18	16	16
2nd diff			0	1	1	2	0

Here the first differences decrease pretty uniformly. But as we have omitted the fourth decimal, the hitch in the 2nd differences is unavoidable, and being too small, may be overlooked. The figures are therefore accurate enough. The last decimals are generally in error not exceeding half a unit for the same reason.

NOTE 4

tabulated values of moon's anomaly in Table 7. For this purpose we must first multiply N by the fraction D/m in order to get the increase in arc in the Moon's equation of centre, and then divide the product by t to get its value in time. Consequently,

$$\therefore E' = \frac{N D}{m t}$$

These two formulæ are similar and can therefore, be combined to obtain the two values by a single effort. Thus—

$$E + E' = \frac{(S + N) D}{m t} \quad Q E D$$

195 The variation in the daily motion of the sun being too small viz, about 2 it can be ignored and the sun's mean daily motion 59 can be used as a constant in the divisor in calculating the equations in time of the sun and the moon. The addition of the moon's equation to the Sun's anomaly, though required by the above theory is practically of no value. For the moon's equation in time (See Table 7) amounts at its maximum to less than half a day, during which time the sun's equation of centre in arc can vary, at the most only by one minute of arc or by five palas which are practically negligible.

196 We shall illustrate the foregoing theory by a numerical example worked out according to the method of the Indian Jyotishins. For this purpose we select the example worked out in Sec. 82 and take from it the anomalies of the moon and the sun which are $341^{\circ} 1$ and $236^{\circ} 2$ respectively. With these arguments, we obtain from Tables 32 and 31 their equations of centre, $+ 98' 1$ and $103' 6$, respectively. Also Table 25 gives 729 for the moon's true daily motion for that day, and we may assume 59 for the sun's motion.

The usual Indian method of calculating the correction to the ending moment of a tithi, due to the equations of centre which

they call *Parakhyā Samskāra* can be easily understood from the following working —

$$\begin{array}{rcccl} \text{☾ s eqn} & \text{☾ s eqn} & \text{☾ s} & \text{☾ s} & \text{Total} \\ (-98 \ 1 + 108 \ 6) & & & & \\ \hline (729 - 59) & = - & 147 \ d + & 162 \ d = + & 015 \ d \end{array}$$

While we get

$$\text{from Tables 7 \& 6} \quad - 133 \ d + 149 \ d = + 016 \ d$$

The Sun's equation $+ 149 \ d$ obtained from Table 6 by employing the moon's mean daily motion 791 is as it ought to be less by about $013 \ d$ than $162 \ d$ obtained by employing the true motion 729. To make up this deficiency theory tells us that we should add $108 \ 6 - 1 \ 89$ to the moon's anomaly 341 0 (See Type of calculation under Sec. 82) and that with the argument 342 8 we should find from table 7 the moon's equation $- 133 \ d$ which is equal to $- 147 \ d + 013 \ d = - 134 \ d$. The totals in both the cases being identical clearly prove the compensation.

NOTE 5

197. The Theory of the calculation of the interval passing between the mean sunrise at Ujjain and the actual sunrise at a given place (vide Sec. 182) is based on the following four assumptions viz. that (1) the Sun moves with its mean motion (2) in the Celestial Equator and that (3) all the towns on the earth have neither longitudes (4) nor latitudes but are crowded together as in an ant hill in the central point of Lanka on the Equator. As none of these assumptions is real corrections must be made for each individual assumption to the extent of its deviation.

The first assumption is corrected by the *Bhujasāra* i.e. the equation of the Sun's centre the second is corrected by the *Udayasāra* i.e. the Right Ascensional difference due to the obliquity of the Ecliptic. The third is corrected by the *Rakhsāra* i.e. longitude and the fourth by *Chāra* which is equal to the excess or defect of the semi-diurnal duration as compared with 6 hours.

NOTE 6

198. Tables.—Table 2 (parts I and II) of the *Adhika* and *Kshaya* months, originally computed by Prof. Kero Laxman Chhatre, is copied from a magazine published in Bombay by the *Djñānaprasāra-Māṇḍalī* in 1851. It is corrected in a few cases by Messrs. Sewell and Dixit, and D. B. Pillai.

Tables 19, 20 and 24 have been adopted from D. B. Pillai's *Chronology*. Table 19 is too simple. D. B. Pillai has not taken the trouble to explain the construction of Tables 20 and 24, a defect which has been made good here with a full explanation. (*Vide* Secs. 121 and 150.) At the very outset in Chapter XI we have in Sec. 120 furnished a formula to which Table 20 may be considered as auxiliary.

The rest of the tables are either specially prepared for this book, or are derived from the author's own treatises.

Tables of increase of elements for odd years and tithis of the *Ārya* and *Brahma Siddhāntas* are not given, the occasion for their use being rare. Those given for the *Sūrya Siddhānta* can be used in their place without appreciable error, as can be seen from the examples worked in Sec. 106, and also from Table 37 of the *Constants* at the end.

The longitude of (Rāhu), as given in Col 7 of Table 3, is the supplement of the distance of the Moon's Node from the Sun's apogee. It is derived from the author's Marathi *Grahaganita*.

NOTE 7

199. Bija or Empirical correction.—It is an Indian Astronomical maxim that the mean positions, after long intervals, require empirical correction. '*Yugāndm parivartena Kālabhedota, Kṣaḍam*' says the *Sūrya Siddhānta*. By '*Kālabheda*' is meant the empirical correction that is not capable of being explained by theory but by a change in the mean motions or by considering it as an arbitrary constant.

Makaranda Lalla and Rajamanganka have respectively suggested empirical corrections to the *Sūrya*, *Ārya* and *Brahma Siddhāntas*

(a) The revolutions of Jupiter in a Mahā Yuga, when corrected for the Bija proposed by Makaranda come to 364212, while those according to *Sūrya Siddhānta* are 364220

(b) The Bija correction to be made to the Moon's anomaly in A D 1600 is $+ 1^{\circ} 56'$ according to Ganesh Dasvajna. This same correction amounts to $+ 1^{\circ} 70'$ when calculated by Burg's Lunar Tables

(c) The Bija corrections which must be made to the mean elements of the *Sūrya Siddhānta* so that they may agree with the mean elements of the Nautical Almanac are in the case of this—

- + 0 014 day to vara
- + 0 014 day to English date
- + 0 330 degrees to the moon's anomaly

These will serve as empirical corrections for a period of one or two centuries in future

NOTE 8

200 The First point of Ashvinī.—Unfortunately there is no bright and unmistakable star near the Ecliptic, either in or near the first point of the first sidereal division of the Hindus called Ashvinī worthy of being referred to as the origin of all the sidereal longitudes. Luckily however there lies in the opposite direction and near the Ecliptic the single and brilliant star Clutra (Spica) the cynosure of all the ancient astronomers. The Indian astronomers deserve therefore high praise for their decision to fix the origin of longitudes at a point diametrically opposite to Clutra which is of Vedic renown. As there are two equinoctial points in the Ecliptic diametrically opposite to each other the Ayanamshas determined with reference to either of them must be equally correct

I shall now show that the general consensus of opinions is in favour of the choice of *Chitra* by quotations both from the works of ancient and modern astronomers and scholars in India

(a) The most ancient and famous Indian astronomer (वरहमिहिर) Varāhamihira (A D 505) has given in his *Pancha Siddhantika* (पञ्चसिद्धान्तिका) the following verse while stating the latitudes and longitudes of only such stars as could be seen occulted by the moon

पित्र्यास्य सप्तमे ऋते चित्रे छयायेम ॥ (अ १४ श्लो २६)

चित्रार्पाथमभागे दक्षिणतः सप्तमे त्रिभिर्हस्ते ॥ (अ १४ श्लो २७)

This important verse was recently brought to my notice by my friend Mr N V Kolhatkar B A Head Master Training School Alibag

The meaning of the verse is plain enough. Herein Varāhamihira states the positions or the longitudes of the moon when she occults the stars Regulus (ऋष) and Spica (चित्रा) or in other word he states the longitudes of the two stars. The moon he says occults Regulus when she arrives at the sixth degree of the Pitrya nakshatra-division and she occults Spica when she arrives at the middle point of the Chitra nakshatra division and has three cubits of south latitude a cubit being equal to 54' 4"

Now the Pitrya division begins at the 120° of longitude consequently the longitude of Regulus must be 126° Chitra being the 14th division the longitude of Spica which corresponds to its middle point must be exactly 180°. Both these longitudes agree in fixing the same first point of Ashvini which is diametrically opposite to the star Spica and is about 43° to the east of the star called mu Pi cum. The 6th cycle ends in A D 291 (Sec. 152) when the tropical longitude of Spica was 180°, and the tropical system came to an end giving place to the sidereal

(b) In respect of the 14th chapter wherein Varāhamihira has given the above verse Dr Thibaut asks in his introduction p 41 'Why Varāhamihira should have confined himself to stating the longitudes and latitudes of seven junction-stars only remains

unaccounted for. Possibly the manuscripts are defective just at that place.

The question is not so difficult as Dr Thibaut thinks it to be. Varahmihira wanted to give a list of such bright stars, the occultation of which by the moon could be seen by the naked eye. For this reason he has omitted all the stars whose latitudes exceeded five degrees and also smaller stars of the third magnitude and below, which disappear on the approach of the moon. The bright star Jyestha seems to be omitted as lying on the border of the zone of occultation. The stars Pushya and Ashlesha given in the list must be as their latitudes show different from those given in the later lists of Yoga taras. It being a list of occultation stars Varahmihira is justified in selecting the 7 stars only. I have done the same in my *Jyotirganita* page 325.

In another place (Introduction, p. 40) Dr Thibaut says a few remarks may be added about what Varahmihira states in XIV (33-38) about the longitudes and latitudes of certain stars. What authority he follows therein we are unable to say.

The answer to this question is given by Varāhamihira himself fourteen centuries ago in the following verse in his *Bṛhat-saṁhitā* edited by Dr Kern.

युद्धं यथा यदा वा मविष्यसदित्यते त्रिवारमै

तद्विज्ञानं वरुणे मया कृतं सूर्यसिद्धांतान् ॥ (अ. १७ श्लो. १.)

भट्टोत्तर — मया वरुणे पंचसिद्धांतिसाध्या सूर्यसिद्धांतान्तरीयं कृतमिति ।

Here by Karana is meant पंचसिद्धांतिका and the *Sūrya Siddhanta* is the original or the old one and not the new or the later one which is now available. The above queries of Dr Thibaut were brought to notice by my son D. V. Ketkar B.A. and the explanations given were also suggested by him.

It should be noted that the words युद्ध and वयसयोग mean the occultation or a near appulse or approach of two heavenly bodies. The Sanskrit word योगसाक्ष should I think be rendered by Conjunction star and not by Junction star, as Dr Thibaut has rendered it in his Introduction to पंचसिद्धांतिका.

(c) The old siddhāntas such as the Sūrya S², the Sōma S², the Brahma S² and the Vriddha-Vasustha S², have all assigned 180° for the longitude of the star Chitrā

The modern astronomers, Mishra Nandramji (Shaka 1665) Jyotishroy Kevalaramji (Shaka 1651) of Jaipur, and Chandra Shekhar Sinha of Cuttock, who were also skilful observers have adopted, in their works, the Ayanāmshās, determined from the observations of the distance of the star Chitra from the Autumnal Equinox

(d) Great scholars like Mahamahopādhyāya Sudhākara Dwivedi of Benares, Shriyuta Lalachandra Sharma of Jaipur and the late A. R. Rājārāja Varmā, M. A., Principal, Sanskrit College, Triven-drum, have in their pamphlets strongly supported the course of fixing the first point of Ashvini situated at 180° from the bright star Chitrā

(e) Sir William Jones in Vol. IV of his works, says "The Lunar year of 360 days (*tithis*) is apparently more ancient than the solar, and began, as we may infer from a verse in the Matsya Purāna with the month of Āshvina, so called because the moon was at the full, when that name was imposed on the first lunar station of the Hindoo Ecliptic the origin of which, being diametrically opposite to the bright star Chitrā (*i. e.* Spica), may be ascertained on our sphere with exactness"

(f) Mr. Davis was a civil servant of the East India Company in A. D. 1790 at Bhāgalpore. In one of his papers published in the second and third volumes of the "Asiatic Researches," Bengal, he says about the Hindoo Ecliptic, "Its origin is considered as distant 180° in longitude from Spica a star which seems to have been of great use in regulating their astronomy and to which the Hindoo tables of the best authority agree in assigning six signs of longitude counting from the beginning of Aśvini their first nakshatra"

(g) M. P. Khareghat, Esq., ICS (now retired), says in his article on the Interpretation of certain passages in the Panch-Siddhāntikā of Varāhamihira, published in Vol. XIX, of the Journal

of the Bombay Branch of the Royal Asiatic Society, A D 1895, on page 134 :—"The Epoch of the Pitāmaha Siddhānta is the second year of the Shaka Era Māgha Sukla 1, when the Sun and Moon were in conjunction at sunrise in the beginning of Dhanuṣṭhā. The data are correct, for on Tuesday, 11th January 80, A D, the sun and moon were in conjunction in Dhanuṣṭhā in the morning. But the conjunction took place not in the beginning of the nakshatra, as now understood, but very near the true longitude of the star Dhanuṣṭhā (Alpha Delphin). The sun was then in the 21st degree from the winter solstice of that year, and in the 27th degree of Capricornus of the moveable Hindu Zodiac, the true longitude of the star is also in the 27th degree of Capricornus. This is extremely important as fixing the true position of the Hindu Zodiac before the introduction of the Babylonian system of signs, Asvini according to this system must have commenced three degrees more to the east than it does now."

(h) From all the above opinions it is clearly manifest that the first point of Asvini was fixed diametrically opposite to the star Chitra, and that its epoch was Shaka year 213 or A D 291, (p 108). Should the reader desire the authority of an Indian observer it is afforded by the above Pitāmaha Siddhāntā, the oldest of all. According to this Siddhānta the longitude of the Star Dhanuṣṭhā was 291 degrees in Shaka year 2. Of course the longitude of Chitra must in that year be $(291 - 114) = 177$ degrees. From these facts we deduce by means of the precessional motion the Shaka year to be $(2 + 210) = 212$ when the longitude of Chitra was $(177 + 3) = 180$ degrees.

REFORMATION OF THE HINDU CALENDAR

(i) From what has been stated in Sec. 152 the reader will be convinced that the star spica was the main Bench Mark of the Sidotropical system of the Aryan Chronology from B C 1193 to A D 291. In the latter year its longitude was exactly 180° , and on this account the year A D 291 was considered as a proper epoch for the commencement of a purely sidereal system of Chronology. But the movement seems to have been opposed by the orthodox,* till at last Aryanātha succeeded in overcoming

* The Libration of the Equinoxes was a subsequent invention calculated to pacify the just fears of the orthodox that the Vernal Equinox would go far away from the mouth of Chaitra.

their opposition [*vide* Sec 152 (c)] by archly adopting for the counter point of Chitrâ a slowly moving point about 10 degrees west of it, and an erroneous sidereal year about 7 palas in excess of that of the ancient Āryans. We must therefore correct these two radical errors if we mean to carry out a thorough reform.

As regards the starting point, the reform will not be a startling one. Because the Epoch of the Meshadi of the Surya S* for Shaka year 1844 as calculated by sec 77, falls on April 13 312 and the true longitude of the Sun for the same Epoch, as calculated from Ketaki (2 eye 2200 days) is found to be $359^{\circ} 38'$. So the distance between the Chitrâ counter point and the moving starting point which was 10 degrees in the beginning of Kaliyuga is at present reduced to -7 minutes only. So also the substitution of the real sidereal year for the erroneous one will secure the fixity of the starting point for all time to come.

We have announced these fundamental reforms in the introductory part of our Ketaki in the following verses —

सारे विमानमोगो मन्मदलमिति १८०° एष्टमुक्त मयेन
 तस्मात् तत्तारकाया अपनश्चिद्वर्षोत्तमोर्वे द्वितीयात् ।
 यथातात् कालिवृत्ते प्रगतिविषयेष्वप्यनारीध भाव्यम्
 तस्माद्वादिदु (१८००) शके यममयनलव २२° नक्षत्र ९° किमसीत् ॥
 गौरीक शरद प्रमाणमपना सार्धे पत्तरांम
 यत्सार्धितर दि वैधमिपुनै प्रत्यक्षतो नृपने ।
 चतु प्राङ् दिक् वर्तमानमपना दृष्टा मुद् दृष्ट
 शुद्धि तद्दिदिदि विषयसर्द्धय मया स्वीकृतम् ॥४॥

SPREAD OF THE REFORMED KETAKI CALENDAR

We have been publishing our Ketaki Panchanga containing these and other reforms for the last 25 years and similar Panchāngas calculated on the basis of our Ketaki, Vajrayanti and Graha ganita, are annually being published in different parts and languages of India as at Pattoor in South Canara at Belgaum in Maharashtra at Ellichpur in the Berars, and at Mathura in Upper India.

Learned men like Pt Madan-Mohan Mālavīya, M.A., of Allahabad, and Prof. Jogesh Chandra Ray, M.A., of Bankura (Bengal), are at present earnestly considering the pressing need of the calendar reform, and the necessity of erecting and conducting suitable observatories for testing the accuracy of Calendars by direct observations. It is to be hoped that sound counsels will ultimately prevail with them and that they will succeed in the near future in their commendable desire.

NOTE 9

201 The date of the Mahābhārata and Bhagavadgītā, B C 470—The late Mr K T Telang has, in his learned introduction to the translation of the Bhagavadgītā, (part of the Series of the Sacred Books of the East, Vol VIII), attempted and almost succeeded in solving this important problem. Beginning from Śaṅkarācārya (8th century A D) he has by means of references and allusions skilfully traced his way up, step by step, through the books of Bana Kālidās Panchatantra, Āpastamba, Patañjali, Baudhāyana, and Pāṇini (4th century B C) and laid down his conclusion in the following words on page 34: "We may, I think lay it down as more than probable, that the latest date, in which the Gītā can have been composed must be earlier than the third century B C, though it is at present impossible to say how much earlier."

(a) Mr B G Tilak has made use of this same method in his Marathi Gītā Rahasya (p 557). He has ultimately expressed his opinion that the date of the Mahābhārata cannot be carried more than 500 years before the Shaka Era. Thus both Messrs Telang and Tilak assign the 4th century B C for the date of the Gītā. However, these methods are indirect and yield negative and often vague results. I have, however, caught hold of a chronological allusion made in the Bhagavadgītā, and making use of a contemporary historical event described in the Mahābhārata, and also of the tables of the Ancient Aryan Chronology, have, I believe, completely and definitely solved the problem.

(b) In identifying himself with the first, foremost, and the best of each kind of things the Divine Śhrīkrishna says in the Bhagavadgītā, X. 35.

necessary to introduce by a royal mandate the new custom of counting from Shravana. This is one out of many instances of the manner how pure truths are often disguised in the puranic myths of India in order to perpetuate them in peoples memory. The legends about Sagara Bhagiratha and Agastya disclose when properly considered important facts in regard to the vast changes in the Earth's surface. The reader may refer for information to my paper read before the First Oriental Conference held at Poona in A D 1919 and recently published in Vol II of its transactions in A D 1923.

NOTE 10

202 Largeteau's Method—The principle of expressing the arguments of inequalities in days of their periods is called Largeteau's Method. It appeared first in 1846 as an addition to the French *Comnaissance des Temps*. Its great merit lies in that it saves completely the time and trouble of computing the arguments. This is very desirable when the number of arguments is unusually large. The arguments when once computed for any date are by this method at once changed into those for any other date by simply adding to them all the same number of the intervening days. For this reason the method has been adopted by Hansen and Delaunay in their lunar tables which contain respectively 52 and 76 inequalities of the Moon's longitude alone. Prof. C. W. Brown has also recently done the same in his lunar tables.

(a) But the case of Indian Chronology in which only two inequalities are involved differs much from that of the Lunar theory in which there arises no necessity of retransforming the periods of arguments into spaces or arcs. In Indian Chronology the way to Nakshatra and Yoga lies through the Sun's anomaly (See Sec 92) which when expressed in days as is done by D. B. Pillai renders the passage very difficult and the explanations unintelligible. For instance the reader might refer to D. B. Pillai's Chronology Chapter XXVIII.

(b) The method of successive approximations employed by Messrs Sewell and Dixit in their Indian Calendar is also objectionable on account of its being very tiresome to the computer Mr Pillai has however the credit of securing both ease and accuracy of computation by voluntarily and generously undergoing himself once for all all the worry of successive approximations by vastly extending the tables See his table IX extending over twelve pages

NOTE II

The Gavamayana Sacrifices

203 The Earliest efforts of the Aryans for Chronology—The correct knowledge of time being considered of vital importance in spiritual and religious matters the duty of keeping correct account of time was entrusted to the *Priests* who were called the *Grāma purohitas*. For this purpose they instituted daily yearly quadrennial and Epoch making sacrifices in which not only the gentry but even kings took part It appears from the *Purana Ninkshana* of the late Mr T G Hale and from the *Gavamayana* of Pandit R Shāmsastri of Mysore that about the time of the *Shatapatha Brahmana* (B C 3100) an era was started by the Aryans in which the priests kept up the count of time by celebrating the *Gavamayana* or the leap-year sacrifices every fourth year There is preserved says R Shāmsastri a record called *Brihadukta* of 460 such sacrifices The era thus lasted 1840 years and ended in about (3100 — 1840) = 1260 B C giving place to *Vedanga Jyotisha* and to the grand cycle era of the Aryans (*Vide Sec 1a2*) The years were called in due order *Kali* *Diapara* *Treta* and *Krita* in succession as the following verse implies —

कलि यमाना भवति वसिष्ठान्तु हारा
वसिष्ठन् त्रेता भवति चरुं वायते इत्यम् ॥

Note—The order of years in this is direct and not reversed like that of the later unwieldy *Yugas*

This verse mentions that **Kali** or the first year begins at sunset the **Dwapara** at midnight the **Treta** at sunrise and the **Krita** at Noon. Instead of adding one day at the end of the fourth year, the original practice seems to commence each year 6 hours later than the preceding.

The similarity in sound of words for the intercalary days used in India Persia and Egypt viz. **Gavamayana** **Gambar** and **Epago-**
men is very striking and suggestive.

The Indian Chronology can be briefly divided into 3 great periods

B C 3100 to 1200 B C The **Gavamayana** Period

B C 1200 to 300 A D The **Grand Cyclic** Period

A D 300 to 1900 A D The **Siddhanta** Period

Or still better into two divisions, viz., the **pre Chitra** and the **post Chitra** periods which are separated by the year
A D 291

NOTE 12

204 Assyria, the land of Astrology and Astronomy — The reference to **Asuras** in the **Shatapatha Brahmana** (khanda VI 1 4) as being more advanced in their knowledge of the seasons is a proof of their civilization being at least as ancient as that of the Aryans whom they soon left far behind in arts and sciences. The Assyrians assisted by the Chaldeans founded mighty empires built great cities and established astronomical observatories at their capitals so that at present Assyriology forms an important branch of Antiquarian research.

The Assyrian Empire was at the height of its glory in the reign of **Shalmaneser**, B C 851. **Ptolemy** of Alexandria has based his calculations in his **Almagest** on the Assyrian Era of **Nabonassar**, which commenced on the 26th of February B C 747. (*Vide* Sec-152, Ex. 2) **Berosus** the historian told **Alexander the Great** that 10 kings ruled before the Deluge for 432000 years, i.e., for 120 Saroi, each of 3600 years.

Although the statement is apparently impossible (*Vide* Sec 210 (c)) yet the number 432000 is very important as it is exactly equal to the years of *Kalyuga*. There were royal observatories at *Ur* and *Chalda* and the Royal astronomers had to submit their reports about their observations twice a month. They used the gnomon and astrolabe in their observations. They marked the Signs of the Zodiac about B C 2200. The cycle of the eclipses was known to them, and the week of 7 days was also in use. They had cycles of 600, 60, and 3600 years called respectively *Naras*, *Sossus* and *Sarus* (*Encyclopædia Britannica* ninth edition).

205 Under such a state of civilized polity and imperial patronage and encouragement to Astronomy it would be unjust to deny to the Assyrian Astronomers the honour of being the first to compile an original work on mathematical astronomy, based on eccentric theory. The countries included in the Assyrian Empire, have even in later years, produced the best observing astronomers. Among them may be mentioned, *Al Mannun*, *Thebit*, *Albateni*, *Alhassan* and *Ulagbeg* (Fig 4)

NOTE 13

206 Gradual spread of the Assyrian Astronomy—It is quite natural for the Western scholars to be partial to their brethren the Greeks. They allege, without any strong and indisputable evidence, that the Hindus must have borrowed their astronomy from the Greeks. On the other hand they admit that the Hindu astronomy is much superior to the Greek in several details, and contains proofs of original and independent development. Had I got a copy of *Ptolemy's Syntaxis* or of its translation called the *Almagest* I could have discussed and decided this question much better than I can at present with the second hand and limited information picked up from encyclopædias and other books of reference.

If at all the Hindus have borrowed from the Greeks any science if we can use the word it is the *Astrology* which is now discarded as groundless by astronomers and scientists and which they (the

Greeks) themselves had borrowed from the Chaldeans. The Hindus frankly acknowledge this fact. Varahmihira quotes in his *Brihatsamhitā*

म्लेच्छा हि यवनास्तेषु सम्यक्शस्त्रमिदं स्थितम् ।

ऋषिपतेऽपि पूज्यते हि पुनर्देवविद्दिग्गजः ॥ (गर्गसंहिता ।)

After calmly considering all the facts and possibilities connected with this question it appears most likely to me, that both the Greeks and the Hindus must have borrowed their knowledge of Astronomy directly from the Assyrian astronomers of Babylon at different periods of its development. By this supposition we can account for and reconcile the agreements and differences of the two schools of astronomy, so remarkable for the likeness of their terminology* and progress.

Small Assyrian astronomical tracts on which the *Romaka*, *Pulisha* and *Saura Siddhantas* were based seem to have reached India as noticed before about the second or the third century A. D. Similar compendiums might have been carried from Babylon in the time of Hipparchus or a century or two later in the time of Ptolemy, 150 A. D. as the map (Fig. 4) shows, to Egypt, Greece and the civilized countries on the borders of the Assyrian Empire.

It is a curious fact that almost all the astronomical works in India have used the Shaka Era as the basis of their computation. This suggests that the Assyrian astronomical tracts might have first entered India by the route of the Persian Gulf through the Deccan with the Shaka invaders who established themselves as kings at Paithan on the Godavari.

The Mahomedan conquerors of Egypt carried with them Ptolemy's *Almagest* to Spain in A. D. 1100 whence it was gradually adapted to the European mode of calculations.

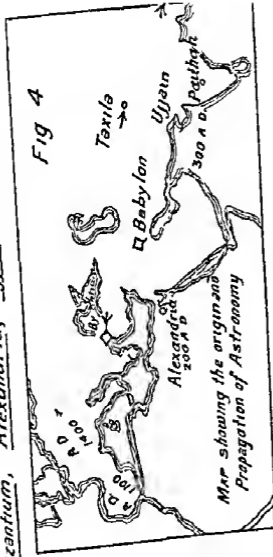
NOTE 14

207 *Babylon was the home of Mayasura*—It is quite natural that one should desire to know the place where Mayasura,

* Thus the words *Arctos* and *Hipia* which are made the topics of a hot discussion lose their importance. They are neither Sanskrit nor Greek, but Chaldean.

Byzantium, Alexandria, Ujjain, Paithan

Fig 4



the Assyrian author of so eminent a work as *Sūrya Siddhānta* lived. In the sequel we hope to answer this question most conclusively by direct evidence from the *Shakalyokta Brahma Siddhānta* and by the indirect evidence of the *Sūrya Siddhānta* itself.

The first eight verses of the *Sūrya Siddhānta* describe in the Puranic style how Mayasura intent upon acquiring the sacred knowledge of Astronomy practised the most difficult penance to please the Sun and how the Sun himself being pleased gave him the knowledge about the movement of the planets.

The following are the verses—The dialogue is mentioned as having taken place when the *Kṛta-Yuga* was nearing its end

सन्नावशिष्टे तु कृते मयनामा महासुर ।
 भ्रातृवयम् विवस्वत तपस्तेषु सुदुश्चरम् ॥
 होषितस्तपसा तेन प्रीतस्तस्मै वरार्पणे
 मदाणां चरितं प्रादान्यथाय सविता स्वयम् ॥

208 The following verse mentioning the place where the dialogue between the sun and Maya took place occurs in the *Shakalyokta Brahma Siddhānta* Adhyaya I verse 169

भूमिच्छाद्वावशांसे लब्धया प्राक् च शास्त्रे ।
 मयाद्य प्रथमे प्रश्ने सूर्यवाक्यमिदं भवेत् ॥

The meaning of this verse is that the sun replied to the first question of Maya at *Shalmala* probably connected with *Shal* manesar from which the longitude of Lanka is equal to one twelfth of the Earth's circumference (i.e. 30 degrees) eastward. The city of *Shalmala* can therefore, be no other than Babylon from which the Longitude of Lanka (*Ujam*) is according to modern determination 31° 15' East. The Arabs still call Babylon *Sham*.

The longitude is here stated according to the *Tulansha* system which was peculiar to the Chaldeans and Assyrians and it is therefore an additional evidence of the *Sūrya Siddhānta* being Assyrian

In this system the directions of longitudes and latitudes are stated in a sense opposed to that adopted by us. They are the directions from a place towards the first meridian and the Equator. Accordingly Ganesh Daivya calls all Indian latitudes as southern 'यमाशा दक्षिण'.

Tandava Krishnacharya who in his Panchanga for Shaka year 1835 has given the longitude of Vizagapatana from Ujjain as $7^{\circ} 35' 30''$ West according to the Tûlansha System quotes in support of it the following verse from the Siddhanta Tatvavivarka of Kamalakara

यदिमे रोक्ताण्याय द्विदि (२०) मार्गं पुर किञ्च ।

यान्दनामिदं वास्ति व्यस्तस्य तद्वत् किञ्च ॥ १७३

मेरुद्वयस्यादत्तं रेखावृत्तं यं यत् तत् ।

स्वदेशादपि तून्नाशा एष्टमूर्ध्वी एव ॥ १७४

209 Here we meet with a clear allusion in Sanskrit to the town Caddai of the Chaldeans is Chaladatti. They were also called the Caddai from the name of the place whence they were supposed to have come originally. If Caddai or Chaldean are first met with in the 9th century B.C. as a small tribe on the Persian Gulf whence they moved northward probably taking part in the invasion led successfully by Salmaneser against the Babylonians in 851 B.C. (*Ibid* *Ind. Britanica* I. ii. 9. p. 138).

This shows the probable connection between the Irû of Nabonassar and the Aryan Irû as suggested by us (*vide* Sec. 152 f). The Encyclopedia also mentions that Tiglath Pileser I captured Babylon in 1130 B.C. and carried his arms into India. The Aryan Irû had been begun in 1193 B.C. and Tiglath Pileser being convinced of its excellence might have invited the Aryan colony of Chronologers or Caddais to go along with him and settle down on the coast of the Persian Gulf in his dominion.

NOTE 15

210 Additional evidence in support of the theory of the Assyrian origin of the *Sūrya Siddhanta*

(a) The *Sūrya Siddhanta* is often quoted in our old works as *Saura* for instance *Saura Māna*, *Saura Bhashya*. It must have been its original Assyrian name. The Arabic *Sur San* which begins with the entry of the Sun into the *Mṛga Nakṣatra* calculated according to the *Sūrya Siddhanta* suggests the same conclusion. The cycle of the rebyres called *Saros* which was undoubtedly known to the Chaldeans may be traced to the original name *Saura*.

(b) The *Shadashitīmukha* holidays described in *Sūrya 8** are said to be of Chaldean origin. They commence with the entry of the Sun in the sign *Libra* for which they had peculiar predilection.

(c) The most significant number of the *Kaliyuga* years 432000 found in the Assyrian works is an indisputable evidence. The seemingly absurd mention in them that 10 kings ruled before the deluge at the rate of 43200 year each can be explained just as we do by giving fictitious names of king to each of the mighty periods called *Manvantaras*. In the language of the Assyrian we might say that six *Manus* viz. *Suyambhuva*, *Swarochiṣi*, *Uttama*, *Tamasa*, *Ruvata*, *Chakras* have reigned during the past 1972944000 year and that the present king *Varasvata* has been ruling since the beginning of the *Kaliyuga*. In our *Sankalpa* we daily repeat *Varasvata Manvantare* without any idea of ridicule. The number of *Kaliyuga* years 432000 appears to be of Indian origin as I might have been carried with them by the Chaldeans in their migration to the shores of the Persian Gulf.

(d) Lastly the most convincing evidence in support of the theory is the complete and astonishing agreement between the times of the Eclipses actually observed during the Assyrian ascendancy and the times calculated exclusively with the elements of the *Sūrya Siddhanta* (that of the moon's node being excepted) without

any correction due to the secular acceleration of the moon's mean motion. Had the elements of the *Sūrya Siddhanta* been derived from much later observations there could have been no such agreement.

(c) We may further suggest that the *Sūrya Siddhanta* elements and inequalities (*vide* Sec. 40) being most accurately determined twenty five centuries ago, are better fitted to be employed in the calculation of the *ancient eclipses* than the modern ones, in which the co-efficient of the moon's acceleration is still somewhat empirical. Theory gives for it $6''.0$ per century, while the observations assign $8''.0$ (*Tables de la lune fondées sur la théorie de Delaunay par Radau*.)

NOTE 16

211. *Bid*, the residence of Bhāskara-charya.—It is regrettable that the question about the place of residence of so eminent an astronomer as Bhāskara-charya should remain so long unsettled. It has been wrongly identified with Bijapur, Beedās and Patan by scholars like Sudhākara and S. B. Dixit.

The colophon at the end of *Goladhāya* says —

आसीत्सपुत्राचलप्रसिद्धिपुरे श्रविषादेन्द्रजने ।

नानासज्जनपण्डित विजयलये शाहिराज मोदी द्विव ॥

भौतसमर्थविचारसाधकपुरी नि शेषविद्यानिधि ।

साधुनामदरपिर्महेश्वरकृती शैवचन्द्रमणि ॥

Mr S. B. Dixit appears to be influenced by the apparent impossibility that *Bid* which is about 200 miles to the east of the Sahyadri range can be said to be in its neighbourhood. On the other hand Bhāskara was no simpleton to speak so loosely and wrongly about the geographical position of his own residence.

The discrepancy is merely apparent and not real. It is due to the failure on the part of Mr. Dixit to mark the broad distinction between the meanings of the words *Arāṭa* and *Kulachola*. The

former is applied to a single range and the latter to the whole family inclusive of the off-shoots emanating from the principal range Bhāskara seems to have specially used the word *Kūlachala* to signify that Bid was situated in the neighbourhood of an off-shoot or branch of Sahyadri and so he leaves no ground for mis-understanding him The readers will please see on a map that Sahyadri sends out a lengthy off-shoot eastwards near Deolali in the Nasik District It runs 200 miles parallel to the Godavari as far off as Beedar and passes on its way near Bid which is situated in the Nizam's territory on the meridian of Ujjain at 19° Latitude

212 By *Bijjala Bid* is meant that Bid belonged to Bijjala who was a vassal prince of the Western Chalukya king Tailapa II in A D 1150 (see Dr Bhandarkar's early History of the Deccan page 90) which is also the date of the Siddhanta Siromani Munishvara the commentator of his works tells us that Bid was situated not far from the Godavari Byapur therefore cannot be the residence of Bhāskara as guessed by Pt Sudhakara of Benares in his *Ganaka tarangini* Nor was he a Karnataka Brahmin as he uses the Sanskritized pure Marathi word *Pith* meaning a board sprinkled with fine red dust on which formerly arithmetical calculations were made But he also uses the word *Kuttaka* for the method of solving indeterminate equations *Kuttaka* is derived from the Kanarese root *kuttu* meaning to pound or pulverize This opens a new problem for research i.e. whether Algebra had its origin in Karnataka There is some ground to believe that Shridhara and Padmanabha whom he mentions as renowned Algebraists must have lived either in Karnataka or in Kalinga the modern Telugu Districts Aryabhatta (A.D. 476) the first of the known Indian Algebraists, was a native of South Canara or Malabar where his *Siddhanta* is still used His commentator Paramadishvara uses the word *Kuttakara* in his *Bhata Dipika* '*Iti dandak Kuttakarab niragrahasagrascheta*' page 47 Aryabhatta edited by Dr H Kern. Leiden A D 1874

CHAPTER XVIII

BIBLIOGRAPHY

213 Early chronologists—In the early half of the eighteenth century Beschi the famous Tamil Scholar and Jesuit missionary in Madurai and Walther a Tranquebar missionary, are said to have published in Latin the accounts of the Indian system of chronology. But it was not until the beginning of the nineteenth century that systematic attempts were made for the compilation of books based on the correct principles and data of the Hindu Siddhantas.

214 Kāla-Sankalita—Under the auspices of the Board of Superintendence of the College of Fort St. George Lieut Col John Warren published under the above title a big quarto Volume of over 400 pages on Indian Chronology. The date of its dedication is 26th February 1825. Assisted by Adr Shesha Brahmam he has incorporated into it the tables of one Vavilal Couduinna a Telugu author and has closely followed the Surya Siddhanta and the Era of Kali Yuga. It contains rule examples and tables for the computations of tithis nakshatras and the positions of the planets.

There appears in the Miscellanea of the Indian Antiquary for January 1891 an able article entitled Examination of some errors in Warren's Kala Sankalita contributed by Mr Shankar B Dixit of Poona.

215 Graha sâdhanâchin Koshtaken—Under this title Prof. Kero Pavuman Chhatre of the Deccan College Poona published in Marathi in A. D. 1860 his lunar and planetary tables based on those of Burg Delambre and Rev Vince. The book begins with chronological rules and tables which are absolutely necessary for the calculation of the Ahargana corresponding to the given title of a lunar solar calendar. With the help of these tables Mr Dixit published in the Indian Antiquary for April 1887 his article on *The method of calculating the week days of the Hindu tithis and the corresponding English dates*.

Prof Chhatre deserves great praise for being the first to undertake the calculation of all the *Adhika* and *Kshaya* months from Shaka year zero to the year 2105. 'They have been,' says D B Pillai, 'copied freely by General Cunningham in his *Indian Eras* and by Mr Patel in his *Chronology* without any check.

216. South Indian Chronological Tables—These were edited by W S Krishnaswami Naidu and Dr Robert Sewell M C S., Madras. They have been reviewed by Mr S B Dixit in the *Indian Antiquary* for October 1890.

217. Dr Herman Jacobi, Ph.D.—He has contributed a number of learned articles and tables on Indian Chronology to *Epigraphia Indica* and to *Indian Antiquary*, A D 1888. He has invented a new and easy method of calculating English dates corresponding to the given Indian dates and *vice versa*. As he has made use of mean motions, the first results are only approximate, and the second ones require much labour.

218. The Indian Calendar.—This has been edited under the joint authorship of Messrs Sewell and Dixit. It covers a period of 16 centuries A D 300—1900. It gives for each year the elements of computation for the beginning of the solar as well as of the lunar years. But these elements are not of much use as the book contains no means of ready reckoning like that of Mr Pillai. The insistence of the method of successive approximation in the calculation of *tithis* has unfortunately, a deterrent effect on computers who are at times required to repeat the approximations ten or fifteen times in order to obtain the correct result.

It contains an extensive and very useful table of *Jyoti* of the Hijri and Christian dates, and another one supplied by Dr Schram of Vienna, containing the dates of all the Solar eclipses visible in India with elements for their computation for a given locality.

The letter press and the foot notes contain very useful information and explanations relating to chronological questions.

219 The Indian Chronology—It is compiled by Diwan Bahadur S. K. Pillai of Madras (A. D. 1911). Of all the books written on Indian Chronology this is the best in point of ease and accuracy. The elements are given for every new moon of the past twenty centuries so that with the help of the eve table, the ending moment of any tithi can be obtained correct within a few palas. But the calculation of B. C. dates is not so easy.

220 The Jantries—These are ephemerides of concurrent dates of two or more eras included within some historical periods.

The Peshwa Period—The late Mr. B. P. Modak professor at the Rajaram College of Kolhapur has published (A. D. 1889) a very useful Jantri of the simultaneous dates. It has greatly facilitated the work of historical research of the Peshwa Period as it contains full details regarding the dates of the Shaka, Vikrama, Râja Shaka, Samvat, Faski, Hijri and the Christian Eras. It is for Shaka years (1600—1811) or for A. D. year (1728—1839).

The Maratha Period—My friend Mr. G. S. Khar, retired Hon. Assistant Engineer has recently (A. D. 1920) presented to the Bharat Itihasa Samshodhaka Mandala of Poona a hundred and fifty year Jephemeris similar in its details to the above Jantri for the Shaka years (1500—1649) or for the A. D. year (1578—1727) i. e. from fifty years before the birth of Shivaji to the death of the first Peshwa Balaji Vishvanath. Mr. Khar could not avail himself of old manuscript almanacs of such distant date. He has undertaken and ably carried out in his old age the most fatiguing work with no other desire than to serve his country.

In his calculation of the five *meeras* he has made use of the Tables of Tithi Chintamani of Ganapati Dnyanya.

TABLES

To be used in calculations.

TABLE 1
Summary of Eras
Vide Secs 2 to 4

No	Era and kind of year	Began in	Calendar	Year begins with	Where or by whom is used
		B C			
1	Julian Era Cur Trop	—4713 Jan	Solar	January 1	Astronomers
2	Jewish Era Cur Sid	—3761 Sep	L S	Tisri 1	The Jews
3	Kaliyuga exp Sid	—3102 Feb	L S	Chaitra Shukla	The Hindus
4	Chinese Era Cur Trop	—2637 Feb	L S	No 1 Shukla	The Chinese
5	Saptarshi Cur Sid	—3076 Apr	L S	Chaitra Shukla	Cashmere
6	Vikrama Exp Sid	—58 Nov	L S	Kartika Shukla	Gujarathi
7	Vikrama Exp Sid	—58 Apr	L S	Chaitra Krishna	Northern India
		A D			
8	Christian Era Cur Trop	+ 1 Jan	Solar	January 1	The Christians
9	Shaka Era Exp Sid	+ 78 Apr	L S	Chaitra Shukla	The Deccan
10	Chedi Cur Sid	+ 247 Oct	L S	Ashvin Krishna	Not in use
11	Vallabha Cur Sid	+ 318 Nov	L S	Kartika Shukla	Kathiawar A D 400 1300
12	Gupta Era Cur Sid	+ 319 Apr	L S	Chaitra Krishna	Central India A D 400 700

Abbreviations—Cur = Current Sid = Sidereal,
 Trop = tropical Exp = expired

Note—Years that begin with Shukla paksha are Amanta
 and those that begin with Krishna-paksha are
 Purnimanta.

The centuries of the Saptarshi Era are generally omitted as
 if it were a cycle of 100 years

TABLE I—(could)

SUMMARY OF ERAS

No	Era and kind of year	Began in	Calendar	Year begins with	Where or by whom used
13	Valayoti, Cur Sid	A. D. + 592 Sep	Solar	Kanya 1	Orissa
14	Amali Cur Sid	+ 592 Oct	L. S.	Bhadra, Shukla 12	Orissa
15	Bengal San Cur Sid	+ 593 Apr	Solar	Vardakha 1	Bengal Assam
16	Magi San, Cur Sid	+ 633 Apr	Solar	Do	Chitagon.
17	Deccan Fasali Cur Sid	+ 591 June	S. Lr	Mirgadi	Revenue accounts
18	Sûrsan or Arabic San, Cur Sid	+ 599 June	Solar	Mirgadi	Was in use during Mahrali & Su primacy
19	Hargh kala Cu Sid	+ 606 Nov			Nepal Not in use now
20	Hiji San, Cur Lunar	+ 612 July	Lunar	Muharam 1	The Musl Imams
21	Kollam Ira Cu Sid	+ 875 Sep	Solar	Kartika 1	North Malabar
	Do do	Do	Do	Shukla 1	South Malabar Kochin Travancore
22	Newar, Fep Sid	+ 879 Nov	L. S.	Kartika Shukla 1	Nepal 878 to 1768 A. D.
23	Chalukya, Fep Sid	+ 1076 Apr	L. S.	Chaitra Shukla 1	Deccan A. D. 1079-1162
24	Laxman Sena, Fep Sid	+ 1118 or + 1108 Nov	L. S.	Kartika Shukla 1	Tidhat Mithila with Shaka Vikram
25	Raja Shaka, Cur Sid	+ 1673 June	L. S.	Jyestha Shukla 13	Dates from Siwa's coronation
26	Coptic, Cur Trop	+ 284	Solar	August 29	In some parts of Egypt

TABLE 2
The Adhika and Kshaya months.
(PART I.)

Calculated on the basis of the *Sūrya-Siddhānta* by Prof.
 Kero Laxman Chhatre

The Intercalary or Adhika months with their Shaka years											
Shra	1	Jye	4	Cha	7	Shra	9	Dha	12	Val	15
	20		23		26		29		31		34
	39		42		*45		47		50		53
	58		61		*61		66	Jye	69		72
Dha	77		80	ish	82		85		88		91
					101		104		107		110
	96		99		120		123		126	Cha	129
	115		118		139		142		145		148
	134		137		154		161		164		167
	153	Val	156	itha	177		180		183		*186
	172		175								
	191		194		198		199		202		*205
Jye	210		213		215	Dha	218		221	ish	223
	229		232		234		237		240		242
	248		251		253		256		259		261
	267	Cha	270	shr	272		275		278		280
	291	Dha	293		291		291	Val	297	Dha	298
	305		307		310		313		316		318
	*324	Cha	327		329		332		335		337
	343		*346		348	Jye	351		354		356
	362	Dha	364		367		370		373		375
	381		383		385		389		392		394
	400	ish	402		405		409	Cha	411		413
	419		421		424		427		429	shr	432
Val	438		440		443		446		*449		451
	457		459		462		465		*467		470
	476		478		481		484		*486		489
	495		497		500	Val	503		505		508
	514		516		519		522		524		527
	*533		535		538		541		543		546
Cha	*552		554		557		560		562	Dha	565
	570	shr	573		576		579		581		584
	589		592		595	Cha	598		600		603
	609		611		614		617		619		622
	627		630	Jye	633		636		638		641
Dha	643		646		650		653		657		660
	664		668		671		*674		678		682
	683		687		690		*693		695		699

Note—The years marked with an asterisk are preceded by a
 kshaya month Dha — Vaisākh — ish = Aishvina

TABLE 2—(contd)
(PART I)—continued
(Based on the Surya Siddhanta)

Adhoka Months with the years of Shaka Era.							
Ch. 1106	Sh. 1406	Dha 1411	Var 1414	Dh 1416	Sh 1419	Jye 1422	
Val 1425	1427	1430	1433	1435	1438	1441	
Cha 1431	1434	1437	1440	1443	1446	1449	
A 1436	1439	1442	1445	1448	1451	1454	
1459	1462	1465	1468	1471	1474	1477	
1480	1483	1486	1489	1492	1495	1498	
1501	1504	1507	1510	1513	1516	1519	
1520	1523	1526	1529	1532	1535	1538	
1541	1544	1547	1550	1553	1556	1559	
1560	1563	1566	1569	1572	1575	1578	
1579	1582	1585	1588	1591	1594	1597	
1600	1603	1606	1609	1612	1615	1618	
1619	1622	1625	1628	1631	1634	1637	
1640	1643	1646	1649	1652	1655	1658	
1659	1662	1665	1668	1671	1674	1677	
1680	1683	1686	1689	1692	1695	1698	
1701	1704	1707	1710	1713	1716	1719	
1720	1723	1726	1729	1732	1735	1738	
1739	1742	1745	1748	1751	1754	1757	
1758	1761	1764	1767	1770	1773	1776	
1777	1780	1783	1786	1789	1792	1795	
1796	1799	1802	1805	1808	1811	1814	
1815	1818	1821	1824	1827	1830	1833	
1834	1837	1840	1843	1846	1849	1852	
1853	1856	1859	1862	1865	1868	1871	
1872	1875	1878	1881	1884	1887	1890	
1891	1894	1897	1900	1903	1906	1909	
1910	1913	1916	1919	1922	1925	1928	
1929	1932	1935	1938	1941	1944	1947	
1948	1951	1954	1957	1960	1963	1966	
1967	1970	1973	1976	1979	1982	1985	
1986	1989	1992	1995	1998	2001	2004	
2005	2008	2011	2014	2017	2020	2023	
2024	2027	2030	2033	2036	2039	2042	
2043	2046	2049	2052	2055	2058	2061	
2062	2065	2068	2071	2074	2077	2080	
2081	2084	2087	2090	2093	2096	2099	
2100	2103	2106	2109	2112	2115	2118	

TABLE 2—(contd.)

(PART II)

(Based on the *Surya Siddhānta*.)

Kshaya or suppressed months in Shaka years with the Adhika months preceding them

Adhika	Kshaya	Adhika	Kshaya	Adhika	Kshaya
Āsh 44	Kār 44	Āsh 501	Pau 501	Kār 1321	Pau 1321
Āsh 63	Mārg 63	Kār 673	Mār 673	Āsh 1397	Mār 1397
Kār 185	Mār 185	Āsh 692	Pau 692	Kār 1443	Mār 1443
Āsh 204	Mār 204	Kār 814	Mār 814	Āsh 1462	Pau 1462
Kār 326	Mār 326	Āsh 933	Pau 933	Āsh 1603	Pau 1603
Āsh 341	Pau 341	Āsh 974	Pau 974	Āsh 1744	Pau 1744
Kār 410	Pau 410	Āsh 1115	Pau 1115	Āsh 1845	Pau 1845
Kār 429	Mār 429	Kār 1180	Pau 1180	Āsh 1904	Mār 1904
Kār 448	Pau 448	Kār 1199	Pau 1199	Kār 1950	Mār 1950
Kār 467	Pau 467	Mār 1218	Pau 1218	Mār 1969	Pau 1969
Āsh 486	Pau 486	Kār 1237	Mār 1237	Kār 2007	Mār 2007
Kār 532	Mār 532	Āsh 1256	Pau 1256	Āsh 2026	Pau 2026
—	—	Kār 1302	Mār 1302	Āsh 2045	Pau 2045

TABLE 3

(Based on the *Sūrya Siddhānta*)

Chronological elements for the Meshādi of each century of Kalyuga.

Kali yuga Era	Shaka Era B S	Chris- tian Era B C	Tithi Shud- dhi	Varā	Chaitan Months, & Date.	Moon's Ano- maly	Sun's Ano- maly	Precession (6) Ayanamsh	Rāhu.
Year	Year	Year	Tithi	Vara	Days		230°		
0	3178	3102	27.795	3 579	F 15 579	241 57	60	-58 30	235.18
1	3178	3101	8.860	4.838	15.838	333 77	-60	59 32	254.54
101	3078	3001	5.343	4.714	16.714	183 18	-60	57.73	30.39
201	2978	2901	1.827	4.589	17 589	32 63	-60	56 06	156.23
301	2878	2801	25.310	4 465	18.465	242.07	-60	54.39	302.08
401	2778	2701	24.793	4.344	19 344	91.51	-60	52.82	77.92
501	2678	2601	21.277	4 216	20.216	300 96	60	51 15	213 76
601	2578	2501	17.760	4 092	21 092	150 39	60	49 48	349 61
701	2478	2401	14 243	3 968	21 968	359 83	-60	47.91	125.45
801	2378	2301	10.727	3.843	22 843	209 28	60	46 24	251 28
901	2278	2201	7.210	3 719	23 719	58 72	60	44.57	37 14
1001	2178	2101	3.693	3 594	F 24 594	268 16	60	43 00	172 98
1101	2078	2001	0.177	3 470	25 470	117 60	60	41 33	308 83
1201	1978	1901	26.660	3 346	26 346	327 01	60	39 66	84 67
1301	1878	1801	23 144	3 221	27 221	176 48	60	38 09	220 41
1401	1778	1701	19 627	3 097	28 097	25 93	-60	-38 42	356.36
1501	1678	1601	16.110	2.973	28.973	235.37	-60	34.75	132.20
1601	1578	1501	12 593	2.848	F 29 848	84.81	-60	33.18	269.04
1701	1478	1401	9 077	2.724	F 1 224	294 25	-60	31.51	43 89
1801	1378	1301	5.560	2 600	2.600	143 69	60	29 84	179.73
1901	1278	1201	2.043	2.475	3.475	353 13	-60	-28 27	315 58
2001	1178	1101	28.527	2.351	4.351	202.58	-60	25.80	91 42
2101	1078	1001	25.010	2 227	5 227	52.02	-60	24 93	227 26
2201	978	901	21.493	2.102	6 102	261.46	-60	23.38	3 11
2301	878	801	17 977	1.978	6.978	110 90	69	21 69	138 45
2401	778	701	14.460	1.854	7.854	320.34	60	-20 02	274 79
2501	678	601	10.993	1.729	M 8 729	169.78	60	-18 45	50 64

TABLE 3—contd

(Based on the *Sūrya Siddhanta*)—contd
 Chronological elements for the Meshādi of each
 century of Kalyuga

Kal yuga Era	Sala Era	Chris tan Era	Tithi Shud dhi	Vara Week days	Chr at en Months & Date	Moon's Ano maly	Sun's Ano maly	Preces sion Ayanaish	Rāhu
B S	B C	B C	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	Year	Year	Tithi	Vara	M Days	.	280"	.	.
2601	578	301	7 427	1 605	M 9 605	19 23	60	-16 78	186 48
2701	478	401	3 910	1 481	10 481	229 67	60	15 11	322 33
2801	378	301	0 393	1 356	11 356	78 11	60	13 54	98 17
2901	278	201	26 877	1 280	12 282	287 55	60	11 87	234 01
3001	178	101	23 380	1 107	13 107	186 99	60	10 20	9 86
3101	B 78	B C 1	19 843	0 983	13 983	346 43	60	8 53	145 70
3201	A 22	A 100	16 327	0 859	14 859	195 87	60	6 96	281 15
3301	122	200	12 810	0 734	15 734	45 32	60	5 29	57 39
3401	222	300	9 293	0 610	16 610	254 76	60	-3 72	193 23
3501	322	400	5 777	0 486	17 486	104 20	60	-2 05	329 08
3601	422	500	2 260	0 361	18 361	313 64	60	-0 38	104 94
3701	522	600	28 743	0 237	19 237	163 08	60	+1 19	240 76
3801	622	700	23 227	0 113	20 113	12 53	60	+2 88	16 81
3901	722	800	21 710	6 983	20 983	221 97	60	+4 53	152 48
4001	822	900	18 193	6 864	21 864	71 41	60	+6 10	288 30
4101	922	1000	14 677	0 740	22 740	280 85	60	+7 77	64 16
4201	1022	1100	11 160	6 615	23 615	130 20	60	+9 44	199 98
4301	1122	1200	7 643	6 491	24 491	339 73	60	+11 01	335 83
4401	1222	1300	4 127	6 367	25 367	189 18	60	+13 65	111 67
4501	1322	1400	0 610	6 242	26 242	38 62	60	+15 35	247 51
4601	1422	1500	31 093	6 118	27 118	248 06	60	+17 02	23 38
4701	1522	1600	23 577	5 993	27 993	99 06	60	+18 59	159 20
4801	1622	1700	20 060	5 869	28 869	308 50	60	+19 76	295 05
4901	1722	1800	16 543	5 745	A 10 745	157 94	60	+21 80	70 89
5001	1822	1900	13 027	5 620	A 12 620	7 39	60	+23 50	206 73
5101	1922	2000	9 511	5 496	A 13 496	216 80	60	+25 13	342 58
5201	2022	2100	5 993	5 372	A 15 372	66 26	60	+27 78	118 42

Note—Column (7) contains supplement of the moon's node
 plus 77°26'

TABLE 4

(Sūrya Siddhānta.)

Increase of Elements in years.

Increase of Elements in Jy.							
Years.	Tithi.	Vāra.	A D day.	Moon's anomaly.	Sun's anomaly.	Precession & Aynā.	Rāhu
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Com.							
1	11°065	1°259	259	92°09	0°00	0°02	19°35
2	22°130	2°517	517	184°19	0°00	03	38°71
3	3°191	3°776	776	276°28	0°00	05	58°06
Leap							
4	14°259	5°035	035	8°38	0°00	07	77°41
8	28°518	3°070	070	16°76	0°00	13	154°82
12	12°778	1°105	105	25°13	0°00	20	232°23
16	27°037	6°140	140	33°51	0°00	27	309°65
20	11°297	4°175	175	41°89	0°00	33	27°06
24	25°556	2°210	210	50°27	0°00	40	104°47
28	9°815	0°245	245	58°64	0°00	47	181°88
32	24°074	5°280	280	67°02	0°00	53	259°29
36	8°334	3°315	315	75°40	0°00	60	336°79
40	22°593	1°350	350	83°78	0°00	67	54°11
44	6°852	6°385	385	92°15	0°00	73	131°53
48	21°112	4°420	420	100°53	0°00	80	208°94
52	5°371	2°445	445	108°01	0°00	87	286°35
56	19°630	0°480	480	117°29	0°00	93	3°78
60	3°890	3°525	525	125°66	0°00	1°00	81°17
64	13°149	3°560	560	134°04	0°00	1°07	158°58
68	2°408	1°595	595	142°42	0°00	1°13	236°00
72	16°667	8°630	630	150°80	0°00	1°20	313°41
76	0°927	4°665	665	159°17	0°00	1°27	30°82
80	15°186	2°701	701	167°55	0°00	1°33	108°23
84	29°445	0°735	735	175°93	0°00	1°40	185°64
88	13°705	5°771	771	184°31	0°00	1°47	263°05
92	27°964	3°806	806	192°68	0°00	1°53	340°46
96	12°223	1°841	841	201°06	0°00	1°60	57°85

TABLE 5

(Surya Siddhānta)

Increase of Elements in the interval of Tithis

Tithis	Vāra	Days	☾ s anomaly	☉ s anomaly	Pre ces	Rāhu	Sun's Motion	
							deg	Days
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	0 984	0 984	12 86	0 87	0 0	0 05	1	1 0
2	1 969	1 969	25 72	1 94	0 0	0 10	-	2 0
3	2 953	2 953	38 58	2 91	0 0	0 15	3	3 0
4	3 937	3 937	51 44	3 88	0 0	0 21	4	4 6
5	4 922	4 922	64 30	4 85	0 0	0 26	5	5 1
6	5 906	5 906	77 16	5 82	0 0	0 31	6	6 1
7	6 890	6 890	90 02	6 79	0 0	0 36	7	7 1
8	7 875	7 875	102 88	7 76	0 0	0 42	8	8 1
9	8 859	8 859	115 74	8 73	0 0	0 47	9	9 1
10	9 844	9 844	128 61	9 70	0 0	0 52	10	10 1
20	19 687	19 687	257 21	19 40	0 0	1 04	20	20 3
30	29 531	29 531	386 80	29 11	0 0	1 57	30	30 4
40	39 374	39 374	514 42	38 81	0 0	2 09	40	40 6
50	49 218	49 218	643 03	48 51	0 0	2 51	50	50 7
60	59 061	59 061	771 63	58 21	0 0	3 13	60	60 9
70	68 905	68 905	899 24	67 91	0 0	3 65	70	71 0
80	78 748	78 748	1026 84	77 61	0 0	4 15	80	81 1
90	88 592	88 592	1154 45	87 32	0 0	4 70	90	91 3
100	98 435	98 435	1282 06	97 02	0 0	5 22	100	101 5
200	196 871	196 871	256 11	194 03	0 0	10 44	200	202 9
300	295 306	295 306	384 17	291 05	0 0	15 06	300	304 4

TABLE 6

Sun's Equation in fractions of a day—For Tithis
Argument = Sun's Anomaly

Arg	0°	30°	60°	90°	120°	150°	Arg
Deg.	Day	Day	Day	Day	Day	Day	Deg
0	000	090	150	178	155	090	30
1	003	093	156	178	153	087	29
2	006	095	159	178	152	085	28
3	010	098	159	178	150	082	27
4	013	101	160	177	148	079	26
5	016	104	161	177	147	077	25
6	019	106	163	177	145	074	24
7	022	108	164	176	143	071	23
8	025	111	165	176	141	068	22
9	029	113	167	176	139	065	21
10	032	115	168	176	137	062	20
11	035	118	169	175	135	059	19
12	038	120	170	175	133	056	18
13	041	122	171	175	131	053	17
14	044	124	172	174	129	050	16
15	047	127	173	173	127	047	15
16	050	129	174	172	124	044	14
17	053	131	175	171	122	041	13
18	056	133	175	170	120	038	12
19	059	135	175	169	118	035	11
20	062	137	176	168	115	032	10
21	065	139	176	166	113	029	9
22	068	141	176	165	111	025	8
23	071	143	176	164	109	022	7
24	074	145	177	163	106	019	6
25	077	147	177	161	104	016	5
26	079	149	177	160	101	013	4
27	082	150	178	159	099	010	3
28	085	152	178	158	095	007	2
29	087	153	178	157	093	003	1
30	090	155	178	155	090	000	0
	+ 330	+ 300	+ 270	+ 240	+ 210	+ 180	

TABLE 7
Moon's Equation for Tiths
Argument = Moon's Anomaly.

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	225	374	412	343		
1	008	231	377	412	339	193	30
2	016	237	380	411	335	187	29
3	024	244	383	410	332	181	28
						175	27
4	032	250	385	409	328	166	26
5	040	256	388	408	323	162	25
6	048	262	391	406	318	156	24
7	056	268	393	405	314	150	23
8	064	273	395	404	309	144	22
9	072	279	397	402	304	138	21
10	079	285	399	400	300	131	20
11	087	290	401	398	295	125	19
12	093	296	403	396	290	119	18
13	102	301	404	394	285	113	17
14	110	306	406	392	280	106	16
15	117	311	407	390	275	100	15
16	123	317	408	388	270	093	14
17	132	322	409	385	263	087	13
18	140	327	411	382	260	090	12
19	147	331	412	380	255	073	11
20	155	336	413	377	250	067	10
21	162	340	413	374	245	060	9
22	169	344	413	371	239	053	8
23	176	348	414	367	234	046	7
24	184	353	414	363	228	040	6
25	191	356	414	361	224	033	5
26	198	360	414	357	217	027	4
27	204	363	414	354	211	029	3
28	211	367	413	351	205	013	2
29	218	370	413	347	199	006	1
30	225	374	412	343	193	000	0
	330	300	270	240	210	180	

TABLE 8

moon's Equation for Nakshatras.

Arg. = Moon's Anomaly.

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg.	Day	Day	Day	Day	Day	Day	Deg.
0	*000	*208	346	*352	317	*179	30
1	*007	*214	349	*381	*313	*173	29
2	*015	*220	352	*380	*309	*167	28
3	*022	*226	*355	*379	*306	*162	27
4	*029	*231	*359	*378	*302	156	26
5	*036	*237	*360	*377	*298	*151	25
6	*044	*243	*362	*376	*294	145	24
7	*051	*248	*364	*375	*290	*139	23
8	*059	*253	*366	*373	*286	*133	22
9	*066	*258	*368	*372	*282	127	21
10	*073	*264	*370	*371	*277	*122	20
11	*080	*269	*372	*369	*273	*116	19
12	*088	*274	373	367	*269	110	18
13	*095	*279	*375	*365	*264	*104	17
14	*102	*283	*376	*363	*260	*098	16
15	*109	*288	377	361	*255	092	15
16	*116	*293	378	*359	250	086	14
17	*123	*299	379	357	*245	*080	13
18	*130	*302	*380	354	*241	*074	12
19	137	*306	381	351	*236	*068	11
20	143	*310	381	*349	*231	*062	10
21	*150	*314	382	346	*226	*056	9
22	*157	*318	*382	*343	*221	*049	8
23	*163	*322	*383	*340	*216	*043	7
24	*170	*326	*383	*337	*211	*037	6
25	*176	*329	*383	334	*206	*031	5
26	*183	*333	*383	*330	*200	*025	4
27	*189	*336	*383	*327	*195	*019	3
28	*195	*339	*383	324	*189	*012	2
29	*201	*343	382	320	*184	*006	1
30	*208	*346	*382	*317	*178	000	0
	371	300	270	240	210	180	

TABLE 9

Sun's Equation for Yogas Arg = O's Anomaly

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	077	131	153	131	077	30
6	017	091	140	152	124	064	24
12	033	103	146	150	114	048	18
18	048	114	150	140	103	033	12
24	064	124	152	140	091	017	6
30	077	131	153	131	077	000	0
	—	—	—	—	—	—	
	330	300	270	240	210	150	

TABLE 10

Moon's Equation for Yogas Arg = ϵ 's Anomaly

Arg	0 +	30 +	60 +	90 +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	190	319	355	295	166	30
6	04*	222	334	350	274	135	24
12	080	251	347	341	251	102	18
18	119	277	355	309	223	069	12
24	155	300	356	313	197	036	6
30	190	319	355	295	166	000	0
	—	—	—	—	—	—	
	330	300	270	240	210	180	

Table 11

Days elapsed from March 0 and April 0

To	From March 0	From April 0	To	From March 0	From April 0
April 0	31	0	October 0	214	183
May 0	61	30	November 0	245	214
June 0	92	61	December 0	275	244
July 0	122	91	January 0	306	275
August 0	153	122	February 0	337	306
September 0	184	153	March 0	365	334
			In leap year	366	335

TABLE 12—(contd.)

Moon's Modern Equation of Centre for Tithis.

Horizontal Arg. = The Monthly Tithi.

Vert. Arg. = Moon's Anomaly — (12 × Monthly Tithis).

Vert. Arg.	The Monthly Tithis.								Vert. Arg.
	8	9	10	11	12	13	14	15	
Day.	Day	Day	Day	Day	Day	Day	Day	Day	
6	+ 630	+ 612	+ 565	+ 480	+ 390	+ 272	+ 140	+ 000	360
12	604	571	510	425	318	196	+ 062	+ 078	348
24	654	508	438	346	236	112	+ 019	+ 154	336
36	481	425	348	254	145	+ 025	+ 100	+ 226	324
48	358	325	246	154	+ 018	+ 064	+ 178	+ 290	312
60	281	218	135	+ 045	+ 050	+ 151	+ 249	+ 343	300
72	161	+ 093	+ 017	063	+ 147	+ 231	+ 311	+ 384	288
84	+ 031	+ 005	+ 100	+ 168	+ 239	+ 303	+ 361	+ 409	276
96	093	+ 155	210	267	319	363	395	417	264
108	218	271	316	355	383	406	412	405	252
120	335	376	408	420	434	427	409	378	240
132	457	465	478	476	459	429	385	326	228
144	522	534	527	496	465	410	341	260	216
156	563	577	551	506	445	366	279	181	204
168	618	595	546	461	401	307	204	+ 092	192
180	627	582	516	432	336	225	+ 115	+ 000	180
192	603	542	459	361	253	139	+ 023	+ 092	168
204	554	475	380	272	155	+ 042	+ 072	+ 179	156
216	478	387	291	167	+ 052	+ 060	+ 163	+ 257	144
228	361	278	167	+ 054	+ 055	+ 157	+ 245	+ 321	132
240	267	166	+ 046	+ 062	102	247	316	367	120
252	141	+ 031	+ 079	177	290	325	371	395	108
264	+ 009	+ 100	200	284	347	388	407	406	96
276	+ 125	226	312	377	419	435	427	398	84
288	250	342	412	455	472	462	427	374	72
300	366	442	492	515	506	471	419	335	60
312	465	524	554	552	521	462	381	288	48
324	544	583	592	568	515	435	336	222	36
336	599	618	608	563	490	394	279	152	24
348	627	628	587	536	447	338	213	+ 078	12
360	+ 630	+ 612	+ 565	+ 480	+ 390	+ 272	+ 140	+ 000	0
22	21	20	19	18	17	16	15	Vert. Arg.	
The Monthly Tithis.								Entry.	

Vide remarks made at the bottom of the preceding page.

TABLE 14

(Based on the *Arya Siddhanta*)Elements for the Meshada of Kalyuga Centuries
3601—5101

Kali years	Shaka years	Kol- lam years	A D years	Tithi (1)	Vāra (2)	A D month date (3)	☾'s anom (4)	☉'s anom (5)
3601	422	- 32	500	2 283	0 361	18 361	309 13	280° 0'
3701	522	225	600	23 751	0 229	19 229	159 03	280° 0'
3801	622	125	700	23 222	0 097	20 097	8 93	280° 0'
3901	722	- 25	800	21 601	6 965	20 965	218 83	280° 0'
4001	822	+ 75	900	18 161	6 833	21 833	68 73	280° 0'
4101	922	175	1000	14 630	6 701	22 701	278 63	280° 0'
4201	1022	275	1100	11 100	6 569	23 569	128 53	280° 0'
4301	1122	375	1200	7 569	6 437	24 437	308 43	280° 0'
4401	1222	475	1300	4 039	6 305	25 305	188 33	280° 0'
4501	1322	575	1400	0 508	6 174	26 174	38 23	280° 0'
4601	1422	675	1500	26 977	6 042	27 042	248 13	280° 0'
4701	1522	775	1600	23 447	5 910	27 910	98 03	280° 0'
4801	1622	875	1700	19 916	5 778	28 778	307 93	280° 0'
4901	1722	975	1800	16 385	5 646	29 646	157 83	280° 0'
5001	1822	1075	1900	12 855	5 514	30 514	7 73	280° 0'
5101	1922	+ 1175	2000	9 325	5 382	31 382	217 63	280° 0'

Note.—The *Arya Siddhanta* is at present used in Malabar, Cochin Travancore the Tamil Districts and part of South Canara.

TABLE 15

(Based on the *Arya Siddhānta*)

To be used in the calculation of the Sankrāntis and of the Solar Months in Tamil and Malabar districts.

Increase of Elements from the moment of Media Sankrānti to each of the subsequent Sankrāntis						
Tamil Solar months	○ long	Malabar Solar months	Tithi (1)	Vāra (2)	Days (3)	○ ano (4)
1 Chittirai	0°	1 Medam	0 000	0 000	0 000	0 0
2 Vaikai	30	2 Edavam	31 416	2 925	30 925	0 0
3 Ani	60	3 Mithunam	63 317	6 323	62 323	44 0
4 Adi	90	4 Karṭṭikam	95 428	2 933	93 933	95 2
5 Avani	120	5 Chingam	127 397	6 401	125 401	147 3
6 Purattasi	150	6 Kanhi	158 923	2 439	156 438	168 4
7 Asvini	180	7 Talam	189 893	4 892	186 892	243 2
8 Karthikai	210	8 Vriśākhā	220 243	6 793	216 798	281 4
9 Mārgaśī	240	9 Dharmas	250 219	1 304	246 394	312 4
10 Tai	270	10 Magaram	280 036	2 655	275 555	337 9
11 Maasi	300	11 Mumbham	309 962	4 112	305 112	281 4
12 Panguni	330	12 Meenam	339 735	5 920	334 920	213 9
1 Chittirai	0	1 Medam	371 065	1 259	365 259	242 9
						271 9
						300 9
						330 0
						0 0

See note below Table 13.

TABLE 16

(Based on the Brahma Siddhanta)

Elements for the Meshadi of Kaliyuga Centuries

3601-5101

Kali years	Shaka years	A D years	Tithi (1)	Vara (2)	A D months (3)	☾ s anom (4)	☉ s anom (5)
3601	422	500	1 357	6 461	Mr 17 461	296° 62	280
3701	522	600	27 816	6 304	18 304	146 58	280
3801	622	700	24 275	6 148	19 148	356 53	280
3901	722	800	20 735	5 992	19 992	206 49	280
4001	822	900	17 194	5 836	20 836	56 44	280
4101	922	1000	13 653	5 679	21 679	266 40	280
4201	1022	1100	10 112	5 523	22 523	116 35	280
4301	1122	1200	6 571	5 367	23 367	926 31	280
4401	1222	1300	3 031	5 211	24 211	176 27	280
4501	1322	1400	29 490	5 054	25 054	26 22	280
4601	1422	1500	25 949	4 898	25 898	236 18	280
4701	1522	1600	22 408	4 742	26 742	86 13	280
4801	1622	1700	18 868	4 585	27 585	296 09	280
4901	1722	1800	15 327	4 429	Ap 9 429	146 04	280
5001	1822	1900	11 787	4 273	11 273	356 00	280
5101	1922	2000	9 246	4 117	12 117	206 96	280

Note—The Brahma Siddhanta is used in Gujarathi and Rajaputana

TABLE 17

(Based on the *Brahma Siddhanta*)To be used in the calculation of Sankrantis in
Gujaratha and Rajaputana

Names of Sankrantis	Months	Increase of elements from Mesha Sankranti to each of the succeeding ones					
		0° Long	Titha (1)	Vara (2)	Days (3)	Ca anom (4)	Os anom (5)
Mesha	Chaitra	0°	0 000	0 000	0 000	00° 0	00° 0
Vrisha	Vaishā	30	31 423	2 932	30 932	44 0	30 5
Mithuna	Jyestha	60	63 336	6 346	62 346	88 5	61 5
Karka	Ashāḍha	90	95 464	9 968	93 968	147 7	92 6
Sinha	Shrāvan	120	127 443	6 447	125 447	198 9	123 6
hanya	Bhādra	150	158 974	2 482	156 482	244 5	154 2
Tula	Ashv n	180	189 912	4 941	185 941	292 4	184 2
Vrischika	Kārtika	210	220 234	6 837	216 837	313 0	213 7
Dhanu	Mārga	240	250 213	1 998	246 298	337 9	242 7
Makara	Pauṣa	270	280 043	2 672	275 672	2 "	271 7
Kumbha	Māgha	300	309 968	4 118	305 118	28 9	300 7
Mina	Phālguna	330	339 738	5 973	334 973	56 3	330 0
Mesha	Chaitra	360	371 065	1 958	365 958	00 1	360 0

See note below Table 13

TABLE 18

Motion in the interval of Nakshatras and Yogas

Nak R	Vāra.	Days	☾'s anom	Yog R	Vāra	Days	☾'s anom	☉'s anom
1	1°012	1°012	13°22	1	0°941	0°941	12°30	0°93
2	2°023	2°023	26°44	2	1°883	1°883	24°60	1°66
3	3°036	3°036	39°68	3	2°824	2°824	36°90	2°78
4	4°048	4°048	52°88	4	3°766	3°766	49°20	3°71
5	5°059	5°059	66°10	5	4°707	4°707	61°50	4°64
6	6°071	6°071	79°32	6	5°649	5°649	73°80	5°57
7	7°083	7°083	92°54	7	6°590	6°590	86°10	6°50
8	8°095	8°095	105°76	8	0°532	7°532	98°40	7°42
9	9°107	9°107	118°98	9	1°473	8°473	110°70	8°35
10	10°119	10°119	132°20	10	2°415	9°415	123°00	9°28
20	20°238	20°238	264°41	20	4°830	18°430	146°00	18°56

Motion of the Elements for days

Days	Tithis	Vāra	☾'s anom	☉'s anom	☾'s node
1	1°015860	1	13°065	0°986	0°053
2	2°031738	2	26°130	1°971	106
3	3°047607	3	39°195	2°957	159
4	4°063476	4	52°260	3°942	212
5	5°079345	5	65°325	4°928	265
6	6°095214	6	78°390	5°915	318
7	7°111083	0	91°455	6°899	371
8	8°126952	1	104°520	7°855	424
9	9°142821	2	117°585	8°870	477
10	10°158690	3	130°650	9°856	0°430
20	20°317380	6	261°300	19°710	1°060

Note—The Sun's apogee being considered fixed, the motion of the sun's anomaly may be taken for that of the mean sun

TABLE 19

The Devan Samvatsaras and the A D years concurring
with them

The month of Chaitra generally concurs with April

Centuries																		
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Samvatsara	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr
1 Prabhava	87	47	07	67	27	87	47	07	67	27	87	47	07	67	27	87	47	07
2 Vibhava	88	48	08	68	28	88	48	08	68	28	88	48	08	68	28	88	48	08
3 Shukla	89	49	09	69	29	89	49	09	69	29	89	49	09	69	29	89	49	09
4 Pramadi	90	50	10	70	30	90	50	10	70	30	90	50	10	70	30	90	50	10
5 Prajapati	91	51	11	71	31	91	51	11	71	31	91	51	11	71	31	91	51	11
6 Argava	92	52	12	72	32	92	52	12	72	32	92	52	12	72	32	92	52	12
7 Shramukha	93	53	13	73	33	93	53	13	73	33	93	53	13	73	33	93	53	13
8 Bhava	94	54	14	74	34	94	54	14	74	34	94	54	14	74	34	94	54	14
9 Jyava	95	55	15	75	35	95	55	15	75	35	95	55	15	75	35	95	55	15
10 Dhatri	96	56	16	76	36	96	56	16	76	36	96	56	16	76	36	96	56	16
11 Ishwara	97	57	17	77	37	97	57	17	77	37	97	57	17	77	37	97	57	17
12 Bahudhanya	98	58	18	78	38	98	58	18	78	38	98	58	18	78	38	98	58	18
13 Pramathi	99	59	19	79	39	99	59	19	79	39	99	59	19	79	39	99	59	19
14 Vikrama	00	60	20	80	40	00	60	20	80	40	00	60	20	80	40	00	60	20
15 Visva	01	61	21	81	41	01	61	21	81	41	01	61	21	81	41	01	61	21
16 Chaitrabhanu	02	62	22	82	42	02	62	22	82	42	02	62	22	82	42	02	62	22
17 Sulbhanu	03	63	23	83	43	03	63	23	83	43	03	63	23	83	43	03	63	23
18 Tara	04	64	24	84	44	04	64	24	84	44	04	64	24	84	44	04	64	24
19 Parthiva	05	65	25	85	45	05	65	25	85	45	05	65	25	85	45	05	65	25
20 Vyaya	06	66	26	86	46	06	66	26	86	46	06	66	26	86	46	06	66	26
21 Sarvagha	07	67	27	87	47	07	67	27	87	47	07	67	27	87	47	07	67	27
22 Sarvadhara	08	68	28	88	48	08	68	28	88	48	08	68	28	88	48	08	68	28
23 Virodha	09	69	29	89	49	09	69	29	89	49	09	69	29	89	49	09	69	29
24 Vikrita	10	70	30	90	50	10	70	30	90	50	10	70	30	90	50	10	70	30
25 Khara	11	71	31	91	51	11	71	31	91	51	11	71	31	91	51	11	71	31
26 Nandana	12	72	32	92	52	12	72	32	92	52	12	72	32	92	52	12	72	32
27 Vajra	13	73	33	93	53	13	73	33	93	53	13	73	33	93	53	13	73	33
28 Jaya	14	74	34	94	54	14	74	34	94	54	14	74	34	94	54	14	74	34
29 Maumati	15	75	35	95	55	15	75	35	95	55	15	75	35	95	55	15	75	35
30 Purvati	16	76	36	96	56	16	76	36	96	56	16	76	36	96	56	16	76	36

To find the Samvatsara for a Shaka year add 78 to it and use the sum as argument of the table

TABLE 21

PART A

Elements of the Muslim Calendar

At commence- ment of	Hijra Era Current			Christian Era Current		
Hijra Era	Cycle	Year	Day	Year	Day	Year
	1	1	1	622	196	1

PART B

Increase of Elements for Cycles

Cycles	1	30	1001	69	40	5
	2	60	21282	39	9	0
	3	90	31533	07	199	1
	4	120	4224	110	194	6
	5	150	53155	145	230	1
	6	180	63799	174	270	0
	7	210	7441	201	30	0
	8	240	85044	293	3	0
	9	270	9592	267	49	7
	10	300	106310	291	02	1
	20	690	212820	582	190	2
	30	990	318030	873	265	7
	40	1290	423240	1165	15	1
	50	1590	531550	1450	119	5
	100	3900	1063100	2910	1	3

TABLE 21

PART C.

Increase of Elements for odd years

Hijri Era		Christian Era			Hijri Era		Christian Era		
Years	Days	Years	Days	Vara	Years	Days	Years	Days	Vara
1	304	0	304	4	16*	5670	15	190	0
2*	709	1	344	2	17	6024	16	184	4
3	1063	2	333	6	18*	6379	17	174	2
4	1417	3	322	3	19	6733	18	163	6
5*	1772	4	312	1	20	7087	19	152	3
6	2626	5	301	3	21*	7442	20	142	1
7*	2481	6	291	3	22	7796	21	131	5
8	2835	7	280	0	23	8150	22	120	2
9	3289	8	269	4	24*	8505	23	110	0
10*	3644	9	259	2	25	8859	24	99	4
11	3898	10	248	6	26*	9214	25	89	2
12	4252	11	237	3	27	9568	26	78	6
13*	4607	12	227	1	28	9922	27	67	3
14	4961	13	216	0	29*	10277	28	57	1
15	5315	14	205	2	30	10631	29	46	5

PART D

Increase of Days to the end of each month

To the end of—	Days	Vara	To the end of—	Days	Vara
1 Muharram	29	1	1 January	30	2
2 Safar	28	0	2 February	28	2
3 Rabi ul awwal	29	4	3 March	29	0
4 Rabi ul aakhir	117	5	4 April	119	0
5 Jumadalawal	147	0	5 May	150	3
6 Jumadalakhir	176	1	6 June	180	5
7 Rajab	206	3	7 July	211	1
8 Shaban	235	4	8 August	242	4
9 Ramzan	265	6	9 September	272	6
10 Shawwal	294	0	10 October	303	2
11 Zil Kad	323	1	11 November	333	4
12 Zil Hijja	353	3	12 December	364	0

V. B.—Years marked with asterisk are Hijri Leap years

TABLE 22

Showing the number of Hryn Month concurring with the
Chartra of the Shaka years

Shak.	H	Shak.	H	Shak.	H	Shak.	H	Shak.	H	Shak.	H	Shak.	H
1369	1	1371	2	1374	3	1377	4	1379	5	1382	6	1385	7
1388	8	1390	9	1393	10	1396	11	1398	12	1401	1	1404	2
1407	3	1409	4	1411	5	1415	6	1417	7	1420	8	1423	9
1426	10	1428	11	1431	12	1434	1	1436	2	1439	3	1442	4
1445	5	1447	6	1450	7	1453	8	1455	9	1458	10	1461	11
1464	12	1466	1	1469	2	1472	3	1474	4	1477	5	1480	6
1482	7	1485	8	1488	9	1491	10	1493	11	1496	12	1499	1
1501	2	1504	3	1507	4	1510	5	1512	6	1515	7	1518	8
1520	9	1523	10	1526	11	1529	12	1531	1	1534	2	1537	3
1539	4	1542	5	1545	6	1548	7	1550	8	1553	9	1556	10
1558	11	1561	12	1564	1	1567	2	1569	3	1572	4	1575	5
1577	6	1580	7	1583	8	1586	9	1589	10	1591	11	1594	12
1596	1	1599	2	1601	3	1603	4	1607	5	1610	6	1613	7
1615	8	1618	9	1621	10	1623	11	1626	12	1629	1	1632	2
1634	3	1637	4	1640	5	1642	6	1645	7	1648	8	1651	9
1653	10	1656	11	1659	12	1661	1	1664	2	1667	3	1670	4
1672	5	1675	6	1678	7	1680	8	1683	9	1686	10	1689	11
1691	12	1694	1	1697	2	1699	3	1701	4	1703	5	1706	6
1710	7	1713	8	1716	9	1718	10	1721	11	1724	12	1727	1
1723	2	1726	3	1729	4	1732	5	1735	6	1738	7	1741	8
1748	9	1751	10	1753	11	1756	12	1759	1	1762	2	1765	3
1767	4	1770	5	1773	6	1775	7	1778	8	1781	9	1783	10
1786	11	1789	12	1792	1	1794	2	1797	3	1800	4	1803	5
1805	6	1808	7	1811	8	1813	9	1816	10	1819	11	1821	12
1824	1	1827	2	1830	3	1832	4	1835	5	1838	6	1840	7
1843	8	1846	9	1849	10	1851	11	1854	12	1857	1	1859	2
1862	3	1865	4	1869	5	1870	6	1873	7	1876	8	1878	9
1881	10	1884	11	1887	12	1889	1	1892	2	1895	3	1897	4
1900	5	1903	6	1905	7	1908	8	1911	9	1914	10	1916	11
1919	12	1922	1	1924	2	1927	3	1930	4	1933	5	1935	6
1938	7	1941	8	1943	9	1946	10	1949	11	1952	12	1954	1
1957	2	1960	3	1963	4	1965	5	1968	6	1970	7	1973	8
1976	9	1979	10	1981	11	1984	12	1987	1	1989	2	1992	3
1995	4	1998	5	2000	6	2003	7	2006	8	2008	9	2011	10
2014	11	2017	12	2019	1	2022	2	2025	3	2027	4	2030	5
2033	6	2036	7	2038	8	2041	9	2044	10	2046	11	2049	12

TABLE 23

Elements of Tithi-Suddhi, A.D. month and date.
 For the Meshādi of Shaka years from 1382—1742 or of A D
 years from 1460—1820 covering the Mogal and
 Marāṭhā Periods

Shaka	Tithi	A D	Vāra	Shaka	Tithi	A D	Vāra	Shaka	Tithi	A D	Vāra
Years	Date			Years	Date			Years	Date		
1382	4.5	1126.8	4	1502	12.3	1127.8	1	1622	20.1	1128.0	5
85	15.7	26.8	2	16	26.5	27.9	6	26	4.3	28.0	1
90	3.0	26.9	0	10	10.5	27.0	4	30	18.8	29.9	8
94	17.3	26.9	5	14	25.1	27.9	14	34	2.8	29.0	2
98	1.5	26.9	3	18	9.3	28.0	0	38	17.1	29.0	2
1402	15.8	26.9	1	22	23.6	28.0	5	42	1.4	29.0	2
96	9.1	27.0	6	26	7.5	28.0	3	46	15.6	28.1	1
10	14.4	27.9	4	30	22.1	28.1	0	50	29.9	28.1	1
14	25.5	27.0	3	34	6.4	28.1	0	54	14.2	29.1	1
18	12.8	27.0	1	38	20.6	28.1	5	58	26.4	29.2	1
1422	27.1	1127.1	6	1542	4.9	1128.2	3	1662	12.7	1129.3	0
26	11.4	27.2	4	46	19.1	28.2	1	66	27.0	29.3	3
30	25.6	27.2	2	50	3.4	28.2	6	70	11.2	29.1	3
34	9.9	27.2	0	54	17.7	28.3	4	74	25.5	29.3	1
38	21.1	27.3	5	58	1.0	28.3	2	78	9.7	29.4	6
42	8.4	27.3	7	62	15.2	28.3	0	82	21.0	9.4	4
46	22.7	27.3	1	66	0.4	28.4	4	86	4.4	9.4	2
50	6.9	27.4	6	70	14.7	28.4	3	90	22.5	9.4	8
54	21.2	27.4	4	74	28.9	28.4	1	94	8.9	9.5	1
1458	5.4	27.4	2	78	13.2	28.5	0	98	21.11	9.5	1
1462	19.7	1127.5	0	1582	27.5	1128.5	4	1702	5.3	1129.6	1
68	4.11	27.5	4	86	11.7	28.6	2	106	19.6	9.6	4
70	15.2	27.5	3	90	26.0	28.6	8	110	3.8	9.6	2
74	2.5	27.6	1	94	10.2	28.6	7	114	18.1	9.7	0
78	16.2	27.6	6	98	24.5	28.7	1	118	2.3	9.7	5
82	1.0	27.6	4	1602	8.4	28.7	1	122	16.6	10.7	5
86	15.2	27.7	2	86	23.0	28.7	6	126	0.9	10.8	7
90	29.4	27.7	0	10	7.3	28.8	4	130	15.1	10.8	1
94	13.8	27.7	5	14	21.5	28.8	2	134	29.4	10.8	5
98	28.0	27.8	3	18	5.5	28.8	0	138	13.6	10.9	3
1502	12.3	1127.5	1	1622	20.1	1128.4	5	1742	27.9	1129.6	1
Increase			for	Cycle				Years			
1	11.1	0.3	1	2	22.1	0.5	2	3	3.2	0.5	3

Note—The fractions of the date to be attached to the integral
 vāra. (Vul. Section 129, Example 3).

TABLE 24

Perpetual Almanac for Christian Calendar

Indexes	1	2	3	4	5	6	0
B C Centuries	3001 2401 1801	2101 2401 1701	3201 2501 1901	4301 2601 1901	3401 2701 2001	3501 2501 2101	3601 2901 2201
	901 01	1001 301	1101 401	1201 501	1301 601	1401 701 1	1501 801 101
A D Centuries	500	400	300	200	100		
(Old Style)	1200	1100	1000 1700	900 1600	800 1500	700 1400	600 1300
(New Style)	1600 2000	1900 300		1800 2200		1700 2100	
Odd years	1 7 12 18 23 29 35 41 46 52 58 63 69 74 80 86 91 97	2 8 13 19 24 30 36 42 47 53 59 64 70 76 81 87 92 98	3 9 14 20 25 31 37 43 49 55 60 66 71 77 82 88 93 99	4 10 15 21 26 32 38 44 49 55 61 67 72 78 83 89 94 99	5 11 16 22 27 33 39 45 50 56 62 68 73 79 84 90 95 00	6 12 17 23 28 34 40 46 51 57 63 69 75 80 86 91 97 02	
Months in a common year	Aug Feb Mar	0 1 2	June 1 2 3 4 5 6 7 8 9 10 11 12	Sep 1 2 3 4 5 6 7 8 9 10 11 12	Apr 1 2 3 4 5 6 7 8 9 10 11 12	Jan 0 1 2 3 4 5 6 7 8 9 10 11 12	May 0 1 2 3 4 5 6 7 8 9 10 11 12
Months in a leap year	Feb Mar Nov Dec	0 1 2 3 4 5 6 7 8 9 10 11 12	June 1 2 3 4 5 6 7 8 9 10 11 12	Sep 1 2 3 4 5 6 7 8 9 10 11 12	Apr 1 2 3 4 5 6 7 8 9 10 11 12	Jan 0 1 2 3 4 5 6 7 8 9 10 11 12	May 0 1 2 3 4 5 6 7 8 9 10 11 12

TABLE 25.

Moon's true daily motion (v) and diameter (d) Arg :— ϵ 's anomaly.

Arg. d. °	0°		30°		60°		90°		120°		150°		Arg. deg.
	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	
0	722	30.0	735	30.0	757	30.5	791	31.2	824	32.0	847	32.8	30
1	723		736		758		792		825		848		29
2	723		736		759		793		826		848		28
3	723		736		760		794		827		849		27
4	723		737		761		796		827		849		26
5			738		762		797		828		849		25
6	724		738		763		798		829		850		24
7	724		739		764		799		830		850		23
8	725		740		765		800		831		851		22
9	725		740		766		802		832		851		21
10	725	30.0	741	30.2	767	30.8	803	31.4	833	32.0	852	32.4	20
11	726		742		768		804		834		852		19
12	726		742		769		805		834		853		18
13	726		743		770		806		835		853		17
14	727		744		771		807		836		854		16
15			745		772		808		836		854		15
16	727		745		773		810		837		854		14
17	728		746		774		811		838		855		13
18	728		746		775		812		839		855		12
19	729		747		776		813		839		856		11
20	729	30.0	749	30.4	776	31.0	814	31.7	840	32.2	856	32.5	10
21	730		749		779		815		841		857		9
22	730		750		781		816		841		857		8
23	731		751		782		817		842		857		7
24	731		752		783		818		843		857		6
25			753		784		819		843		857		5
26	732		754		785		820		844		858		4
27	732		754		787		821		845		858		3
28	733		755		788		822		846		859		2
29	734		756		789		823		846		859		1
30	735	30.0	757	30.5	791	31.2	824	32.0	847	32.5	859	32.5	0
	340°		300°		220°		240°		210°		150°		

TABLE 26

Moon's Diameter (a) and (b), Arg = γ , (Vide Sec 163)

Arg γ	Dia	(a)	(b)	Arg γ	Dia	(a)	(b)	Arg γ	Dia	(a)	(b)
700	29 8	54 7	24	770	30 8	57 0	25	820	31 8	59 5	27
730	40 0	55 2	24	780	31 0	57 6	26	830	32 0	60 0	27
740	40 2	55 6	24	790	31 2	58 0	26	840	32 2	60 4	27
750	30 4	56 1	25	800	31 4	58 4	26	850	32 4	60 8	27
760	30 6	56 6	25	810	31 6	58 9	26	860	32 6	61 2	28
770	30 8	57 0	25	820	31 8	59 4	27	870	32 8	61 8	28

TABLE 27

Moon's Latitude

Arg = D in a solar Eclipse, Vide Sec 163 167

Arg = D + 180° in a lunar Eclipse

Argument	-	343	344° 45	345	346° 30	347	348° 15	349	350° 0	351° 45	352	353° 30	354	355° 15	356	357° 0	358° 45	359	360° 0
+	12	11	10	9	8	7	6	5	4	3	2	1	0	0	1	2	3	4	5
+	165	170	175	171	176	173	174	177	176	172	170	168	166	164	162	160	158	156	154
-	192	191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176	175	174
Lat		60 45	59 55	59 15	58 40	58 0	57 30	57 0	56 30	56 0	55 30	55 0	54 30	54 0	53 30	53 0	52 30	52 0	51 30

TABLE 28

Semiduration of ϵ in Eclipse Arg = γ and (a-b) Sec 163

Eclipse Arg = (γ) and (a-b) Sec. 165									
(Arg (m, t) (a-b))	Argument (a)								
	54	55	56	57	58	59	60	61	62
Pal	Pal	Pal	Pal	Pal	Pal	Pal	Pal	Pal	Pal
10	122	119	117	115	113	110	108	106	104
15	171	167	164	161	158	155	152	149	147
20	200	197	193	189	186	183	179	176	173
25	225	221	217	213	208	205	201	198	195
30	241	235	230	227	223	219	216	212	209
35	250	245	240	237	233	230	226	223	219
40	257	252	247	244	240	236	233	229	226
45	262	257	252	248	244	240	236	233	229
50	266	262	258	254	250	246	242	239	235
	269	265	261	257	253	249	245	242	238
			281	278	274	269	264	260	256
				278	274	270	267	264	261

TABLE 29

Approximate Ghati of the middle of a Solar Eclipse
Arg: The Ghati of New Moon

Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid
gh	gh	gh	gh	gh	gh	gh	gh	gh	gh	gh	gh
0	26	5	1	10	6	15	15	20	24	25	29
1	57	6	2	11	8	16	17	21	25	26	30
2	58	7	3	12	9	17	19	22	26	27	31
3	59	8	4	13	11	18	21	23	27	28	32
4	60	9	5	14	13	19	22	24	28	29	33
5	1	10	6	15	14	20	24	25	29	30	34

TABLE 30

Nats or Parallel in the Moon's Latitude
Arg: Sidereal Time T, and the latitude of the place

Nts T		Degrees of North Latitude							
gh	gh	3°	10°	15°	20°	25°	30°	35°	40°
0	60	-27	-31	-35	-39	-42	-45	-48	-51
1	57	-26	-30	-34	-38	-41	-44	-47	-50
2	54	-24	-28	-31	-35	-39	-42	-45	-48
3	51	-19	-23	-27	-30	-34	-37	-40	-43
4	48	-12	-16	-20	-24	-28	-31	-34	-37
5	45	-3	-7	-11	-15	-19	-22	-25	-28
6	42	+2	-2	-6	-10	-14	-17	-20	-23
7	39	9	+4	-1	-5	-9	-12	-15	-18
8	36	14	9	+4	-1	-5	-8	-11	-14
9	33	17	12	7	+3	-1	-4	-7	-10
10	30	+18	+13	+8	+3	-2	-5	-8	-11

TABLE 31

Sun's Equation of the Centre Arg. = \odot 's anomaly.

Arg	0	30°	60°	90°	120°	150°	Arg
Deg							Deg
0	0°0	65°6	113°2	120°7	113°2	65°6	30
1	2°8	67°5	114°3	120°7	112°0	63°6	29
2	4°7	69°5	115°4	130°7	110°8	61°5	28
3	7°0	71°1	116°4	130°6	109°6	59°6	27
4	9°3	73°1	117°5	130°4	108°3	57°6	26
5							
6	11°6	75°1	118°5	130°7	107°0	55°5	25
7	13°9	77°0	119°4	130°0	105°7	53°5	24
8	16°2	78°8	120°3	129°8	104°4	51°4	23
9	18°5	80°6	121°2	129°5	103°0	49°3	22
10	20°8	82°4	122°0	129°1	101°6	47°2	21
11							
12	23°0	84°1	122°8	128°7	101°1	45°0	20
13	25°3	85°9	123°6	128°3	98°6	42°9	19
14	27°5	87°5	124°3	127°9	97°1	40°7	18
15	29°8	89°2	125°0	127°4	95°6	38°6	17
16	32°0	90°8	125°7	126°8	94°0	36°4	16
17							
18	34°2	92°5	126°1	126°4	92°5	34°2	15
19	36°4	94°1	126°8	125°7	90°8	32°0	14
20	38°6	95°6	127°4	125°0	89°2	29°8	13
21	40°7	97°1	127°6	124°1	87°5	27°5	12
22	42°9	98°6	128°3	123°6	85°9	25°1	11
23							
24	45°1	101°1	128°7	122°8	84°1	23°0	10
25	47°2	102°6	129°1	122°0	82°4	20°8	9
26	49°3	103°0	129°5	121°2	80°6	18°5	8
27	51°4	104°4	129°8	120°3	78°8	16°2	7
28	53°5	105°7	130°6	119°4	77°0	13°0	6
29							
30	55°5	107°0	130°2	118°5	75°1	11°6	5
31	57°6	108°4	130°4	117°5	73°3	9°3	4
32	59°6	109°6	110°6	116°4	71°4	7°0	3
33	61°8	110°8	110°7	115°4	69°5	4°7	2
34	63°6	112°0	110°7	114°3	67°5	2°3	1
35	65°6	113°2	110°7	111°2	65°6	0°0	0
Arg.	+ 130°	+ 90°	+ 270°	+ 210°	+ 150°	+ 100°	Arg

TABLE 32

Moon's equation of the Centre $\Delta g = \epsilon$'s anomaly

Arg	0	30°	60°	90°	120°	150°	Arg
Deg							Deg
0	0° 0	150° 7	260° 9	301° 7	260° 0	150° 7	30
1	5° 4	155° 2	263° 4	301° 6	258° 2	145° 2	29
2	10° 7	159° 7	266° 0	301° 5	254° 4	141° 6	28
3	16° 0	164° 1	268° 1	301° 4	252° 8	137° 0	27
4	21° 3	168° 5	270° 8	300° 9		132° 3	26
					249° 7		
5	26° 6	172° 8	273° 1	309° 5	246° 7	127° 8	25
6	31° 9	177° 1	275° 3	309° 0	243° 6	122° 5	24
7	37° 1	181° 2	277° 4	299° 4	240° 8	119° 0	23
8	42° 4	185° 4	279° 4	299° 7	237° 5	113° 2	22
9	47° 6	189° 5	281° 4	297° 5	234° 5	108° 3	21
10	52° 8	193° 5	283° 3	297° 0	230° 9	103° 4	20
11	58° 0	197° 5	285° 1	296° 1	227° 4	98° 5	19
12	63° 1	201° 4	286° 7	295° 1	223° 9	93° 5	18
13	68° 1	205° 3	288° 1	293° 8	220° 4	88° 5	17
14	73° 4	209° 1	289° 5	292° 4	216° 7	83° 5	16
15	78° 5	212° 9	291° 7	291° 0	212° 9	78° 5	15
16	83° 5	216° 7	292° 4	290° 5	209° 1	73° 4	14
17	88° 5	220° 4	293° 8	289° 1	205° 3	68° 1	13
18	93° 5	223° 9	295° 1	286° 7	201° 4	63° 1	12
19	98° 5	227° 4	296° 1	285° 1	197° 5	58° 0	11
20	103° 4	230° 9	297° 0	283° 3	191° 5	52° 8	10
21	108° 3	234° 4	297° 8	281° 4	189° 5	47° 6	9
22	113° 2	237° 5	298° 7	279° 4	185° 4	42° 4	8
23	118° 0	240° 8	299° 4	277° 4	181° 2	37° 1	7
24	122° 8	243° 6	300° 0	275° 3	177° 1	31° 9	6
25	127° 8	246° 7	300° 5	273° 1	172° 8	26° 6	5
26	132° 3	249° 7	300° 9	270° 8	168° 2	21° 3	4
27	137° 0	252° 8	301° 3	268° 4	164° 1	16° 0	3
28	141° 6	254° 2	301° 5	266° 0	159° 7	10° 7	2
29	146° 2	256° 2	301° 6	263° 4	153° 2	5° 4	1
30	150° 7	260° 0	301° 7	260° 0	150° 7	0° 0	0
Arg.	+ 310°	+ 290°	+ 270°	+ 250°	+ 230°	+ 190°	Arg

TABLE 33

For Charakāla, use Arg = Sun's Tropical longitude

„ Udayāntara, use Arg = 2 (Sun's Tropical longitude)

„ Bhujāntara, use Arg = Sun's anomaly.

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Palas	Palas	Palas	Palas	Palas	Palas	Deg
1	0° 00	0° 09	17° 53	20° 71	17° 53	0° 09	90
1	0° 32	0° 39	17° 71	20° 09	17° 32	0° 37	29
2	0° 63	10° 29	17° 09	20° 67	17° 11	0° 07	28
3	0° 97	10° 59	18° 07	20° 63	16° 00	0° 75	27
4	1° 30	10° 09	18° 20	20° 02	16° 69	8° 14	26
5	1° 02	11° 19	18° 13	20° 60	16° 48	8° 13	25
6	1° 03	11° 48	18° 62	20° 57	16° 28	7° 82	24
7	2° 28	11° 76	18° 77	20° 50	16° 02	7° 50	23
8	2° 63	12° 05	18° 02	20° 41	15° 77	7° 19	22
9	2° 06	12° 36	19° 07	20° 37	15° 52	6° 87	21
10	3° 29	12° 62	19° 22	20° 31	15° 27	6° 55	20
11	3° 63	12° 30	19° 37	20° 24	15° 02	6° 24	19
12	3° 95	13° 19	19° 52	20° 18	14° 77	5° 92	18
13	4° 28	13° 45	19° 63	20° 07	14° 50	5° 60	17
14	4° 01	13° 71	19° 74	19° 96	14° 24	5° 27	16
15	4° 53	13° 99	19° 85	19° 83	13° 98	4° 95	15
16	4° 27	14° 21	19° 96	19° 74	13° 71	4° 61	14
17	5° 60	14° 50	20° 07	19° 63	13° 45	4° 29	13
18	5° 02	14° 77	20° 14	19° 52	13° 19	3° 95	12
19	6° 24	15° 02	20° 21	19° 37	12° 90	3° 63	11
20	6° 55	15° 27	20° 31	19° 22	12° 62	3° 29	10
21	6° 47	15° 52	20° 37	19° 07	12° 33	2° 96	9
22	7° 19	15° 77	20° 44	18° 92	12° 05	2° 63	8
23	7° 50	16° 02	20° 50	18° 77	11° 76	2° 29	7
24	7° 82	16° 26	20° 57	18° 62	11° 49	1° 95	6
25	8° 13	16° 46	20° 60	18° 43	11° 19	1° 62	5
26	9° 41	16° 69	20° 62	18° 25	10° 89	1° 30	4
27	8° 75	16° 00	20° 65	18° 07	10° 59	0° 97	3
28	9° 07	17° 11	20° 67	17° 89	10° 29	0° 65	2
29	9° 37	17° 32	20° 69	17° 71	9° 09	0° 33	1
30	9° 69	17° 53	20° 71	17° 53	9° 09	0° 00	0
Arg	330°	300°	270°	240°	210°	180°	Arg

TABLE 34

The Equinoctial Shadow in digits

Argument=Latitude of Place.

Latitude	Digits	Latitude	Digits	Latitude	Digits
0°	0°00	15°	3°22	30°	6°43
1	0°21	16	3°44	31	7°21
2	0°42	17	3°67	32	7°50
3	0°63	18	3°90	33	7°79
4	0°84	19	4°13	34	8°09
5	1°05	20	4°37	35	8°40
6	1°26	21	4°61	36	8°72
7	1°47	22	4°85	37	9°04
8	1°68	23	5°09	38	9°37
9	1°90	24	5°34	39	9°72
10	2°11	25	5°59	40	10°07
11	2°31	26	5°85	41	10°43
12	2°55	27	6°11	42	10°80
13	2°77	28	6°39	43	11°19
14	2°99	29	6°65	44	11°59
15	3°22	30	6°93	45	12°00

TABLE 35

*Semiduration of total phase in lunar eclipse.*Arguments= b and $(b-l)$

$(b-l)$	b				
	24	25	26	27	28
	<i>Palas.</i>	<i>Palas</i>	<i>Palas</i>	<i>Palas</i>	<i>Palas</i>
2	52	50	48	47	46
4	72	69	67	65	63
8	95	92	90	88	86
12	111	108	106	103	101
16	124	118	116	113	111
20	127	124	122	120	118
24	128	127	124	124	122
28	—	—	125	124	125

TABLE 36

Logna and Sidereal Time.

For Lagna, Arg:=Latitude and Sidereal Time.

For Sidereal Time, Arg.=Latitude and Logua

[illegible]

TABLE 36—(contd.)

Lagna and Sidereal Time

For Lagna; Arg = Latitude and Sidereal Time

For Sidereal Time; Arg = Latitude and Lagna

Arg side- real	North Latitude							
	0°	5°	10°	15°	20°	25°	30°	35°
Ghati	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna

30	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
31	164.0	163.8	163.6	163.4	163.1	162.9	162.7	162.5
32	170.5	170.1	169.7	169.2	168.8	168.4	168.0	167.5
33	177.0	176.3	175.6	175.0	174.4	173.8	173.2	172.5
34	183.4	182.5	181.6	180.9	180.0	179.2	178.4	177.5
35	189.7	188.6	187.5	186.5	185.5	184.6	183.5	182.5
36	195.9	194.6	193.4	192.2	191.0	189.9	188.7	187.4
37	202.0	200.5	199.1	197.6	196.5	195.2	193.8	192.4
38	207.9	206.4	204.9	203.4	201.9	200.4	198.9	197.3
39	213.8	212.1	210.5	209.1	207.3	205.6	204.0	202.2
40	219.6	217.8	216.1	214.4	212.6	210.9	209.0	207.1
41	225.3	223.5	221.6	219.8	218.0	216.1	214.1	211.9
42	230.9	229.0	227.1	225.2	223.2	221.2	219.1	216.9
43	236.5	234.5	232.6	230.6	228.6	226.5	224.2	221.9
44	242.0	240.0	238.0	236.0	233.9	231.7	229.4	226.9
45	247.5	245.5	243.5	241.4	239.3	237.0	234.2	231.8
46	253.0	251.0	248.9	246.8	244.7	242.3	239.6	236.8
47	258.5	256.6	254.5	252.4	250.2	247.8	245.2	242.4
48	264.1	262.2	260.1	257.9	255.8	253.4	250.7	247.2
49	269.7	267.8	265.8	263.8	261.5	259.1	256.4	253.4
50	275.4	273.6	271.7	269.6	267.4	265.0	262.3	259.8
51	281.2	279.5	277.7	275.6	273.5	271.1	268.4	265.6
52	287.1	285.4	283.7	281.8	279.8	277.4	274.8	271.4
53	293.0	291.5	289.9	288.2	286.1	284.1	281.5	278.5
54	299.1	297.8	296.3	294.7	293.0	290.9	288.6	285.1
55	305.3	304.1	302.9	301.5	300.0	299.1	296.0	293.9
56	311.6	310.7	309.6	308.4	307.1	305.6	303.7	301.0
57	318.0	317.3	316.4	315.5	314.5	313.3	311.8	310.0
58	324.5	324.0	323.4	322.8	322.1	321.2	320.2	319.0
59	331.0	330.7	330.4	330.1	329.5	329.2	328.5	328.3
60	337.5	337.5	337.5	337.5	337.5	337.5	337.5	337.5

TABLE 37
The Constants

Elements	Surya S°	Arya S°	Brahma S°
In a Mahāyuga of 4320000 yrs	Revolutions	Revolutions	Revolutions.
Days	1577 917 823	1577 917 500	1577 916 450
Suns	4 320 000	4 320 000	4 320 000
Moon's	57 753 336	57 753 336	57 753 300
Apogee of moon	468 203	468 214	458 106
Jupiter's	361 220	364 224	361 226
In a year			
☉'s Anomaly	17° 25' 581 762	17° 25' 581 442	17° 25' 588 218
Tithis	371° 06' 483 333	371° 06' 483 333	371° 06' 458 333
Days	365° 25' 873 648	365° 25' 878 055	365° 25' 843 750
The period of the	Days	Days	Days.
Lunar Month	29° 53' 068 795	29° 53' 050 250	29° 53' 058 790
Anom. Month	27° 55' 469 990	27° 55' 460 187	27° 55' 454 648
Sideres' Month	27° 32' 167 416	27° 32' 160 844	27° 32' 166 731
Mean latitude (by S. B. Dixit's)	499 March 21° 25'	499 March 21° 25'	499 March 21° 25'
Sun ..	11 29° 54' 42"	0 0° 0' 0"	0 0° 51' 45"
Sun's apogee	2 17 15 0	2 18 0 0	2 17 54 0
Moon ..	9 10 19 33	9 10 45 0	9 11 31 46
Moon's apogee	1 0 53 51	1 5 42 0	1 7 21 3
Greatest Equator of Centre	*		
Sun's ..	2 10 30	2 11 55	2 10 30
Moon's ..	5 2 24	5 11 48	5 1 45

TABLE 38

Showing the years of other Eras, concurrent
with the year A D 1000

Eras	Chaitra Mesha April A D 1000	Jyestha Mithu June A D 1000	Bhadra Kanya Sept A D 1000	Ashvin Tula Oct A D 1000	Kartik Arschika Nov A D 1000	Year Begins with
	Year	Year	Year	Year	Year	Year
1 Kali yuga	4101	4101	4101	4101	4101	Shukla
2 Saptarshi	4076	4076	4076	4076	4076	Do
3 Vikrama North	1057	1057	1057	1057	1057	Krishna
4 Shaka	922	922	922	922	922	Shukla
5 Gupta	681	681	681	681	681	Krishna
6 Magi	362	362	362	362	362	Mesha
7 Bengali Sar	407	407	407	407	407	Mesha
8 Harshakala	394	394	394	394	394	Mesha
9 Chalukya	-76	-76	-76	-76	-76	Shukla
10 Del. Fasali	410	410	410	410	410	Margadi
11 Arabi Sar	400	401	401	401	401	Do
12 Raja Shaka	674	673	673	673	673	Shukla
13 Coptic	716	716	717	717	717	September
14 Amali	407	407	408	408	408	Shukla
15 Vilayati	407	407	408	408	408	Kanya
16 Kellam	175	175	176	176	176	Kanya
17 Chedi Kalchuri	752	752	752	753	753	Krishna
18 Jewish Era	4760	4760	4760	4761	4761	Shukla
19 Vikram South	1056	1056	1056	1056	1057	Shukla
20 Vallabhi	681	681	681	681	682	Krishna
21 Nivar	120	120	120	120	121	Krishna
22 Laxman Sen	-119	-119	-119	-119	-118	Do
	-109	-109	-109	-109	-109	Do
	5713	5713	5713	5713	5713	January
23 Julian	3637	3637	3637	3637	3637	Mesha
24 Chinese	1453	1453	1453	1453	1453	Shukla
25 Hijari						Shukla

Note—(1) The year of the above eras concurring with any given A D year other than 1000 can be obtained by simply correcting the above years by its defect under or excess over A D 1000 taking care to lessen the defect by unity in the case of the B C years. Vide Sec 145

(2) The vertical thick lines mark the change of years

TABLE 39

Supplementary to Table 5

(Based on the Surja Siddhanta)

Increase of Elements to be used in verification

T th	Vāca	Days	Q s a. ore	O s anom	T th	Vāca	Day	Q s anom	O s a. cm
11	3 83	10 83	141 5	10 7	21	6 6	20 6	270 0	0 4
12	4 81	11 81	154 3	11 6	22	0 66	21 66	287 9	01 3
13	5 80	12 80	167 2	12 6	23	1 64	22 61	295 5	02 3
14	6 78	13 78	180 0	13 6	24	2 62	23 62	303 6	23 3
15	0 77	14 76	192 9	14 6	25	3 61	24 61	311 5	04
16	1 75	15 5	205 5	15	26	4 59	25 59	319 4	05 2
17	2 73	16 73	218 6	16 5	27	5 58	26 58	327 2	06 0
18	3 72	17 7	231 5	17 5	28	6 56	27 56	335 1	07 0
19	4 70	18 70	244 3	18 4	29	0 55	28 55	342 9	08 1
20	5 69	19 69	257 2	19 4	30	1 53	29 53	350 8	09 1

TABLE 40

For conversion of fractions of a Day into Gatis and Palas

Cent. me.	0	1	2	3	4	5	6	7	8	9
	G P	A P	E P	E P	S P	S P	S P	S P	S P	E P
00	0 0	0 36	1 12	1 48	2 24	3 0	3 36	4 12	4 48	5 24
10	0 0	6 36	7 12	7 48	8 24	9 0	9 36	10 12	10 48	11 24
20	12 0	12 36	13 12	13 48	14 24	15 0	15 36	16 12	16 48	17 24
30	18 0	18 36	19 12	19 48	20 24	21 0	21 36	22 12	22 48	23 24
40	24 0	24 36	25 12	25 48	26 24	27 0	27 36	28 12	28 48	29 24
50	30 0	30 36	31 12	31 48	32 24	33 0	33 36	34 12	34 48	35 24
60	36 0	36 36	37 12	37 48	38 24	39 0	39 36	40 12	40 48	41 24
70	42 0	42 36	43 12	43 48	44 24	45 0	45 36	46 12	46 48	47 24
80	48 0	48 36	49 12	49 48	50 24	51 0	51 36	52 12	52 48	53 24
90	54 0	54 36	55 12	55 48	56 24	57 0	57 36	58 12	58 48	59 24
For Mile times	0 0	0 4	0	0 11	0 14	0 18	0 22	0 26	0 30	0 3

Example—Sec 8th Type of Cal 0 264 day Or 11 s 06 = 15 ph
 36 p and 004 = 14 palas So 0 264 day = 15 gl 09 p

APPENDIX I

Names of Nakshatras

- 1 Āshvini 2 Bharani 3 Kṛtikā 4 Rōhini 5 Mṛga 5 Ārdrā
 7 Punarvasu 8 Pushya 9 Āshleshā, 10 Maghā 11 Pūrvā Phāl
 gum 12 Uttarā Phālgum 13 Hasta 14 Chitrā 15 Swātī 16
 Viśākhā 17 Anurādhā 18 Jyesthā 19 Mūla 20 Pūrvāṣṭhādā
 21 Uttarāṣṭhādā 22 Shravana 23 Dhanisthā 24 Shatātārakā
 25 Pūrvā Bhādrapadā 26 Uttarā Bhādrapadā 27 Revatī

Names of Yogas

- 1 Viśkambha 2 Prati 3 Āyushamat 4 Saubhāgya 5 Sho-
 bhana 6 Atiganda 7 Sukarman 8 Dhṛti 9 Shūla 10 Ganda
 11 Vṛddha 12 Dhruva 13 Vyāghāta 14 Harshana 15 Vajra
 16 Siddhi 17 Vyatipāta 18 Varyān 19 Pangha 20 Shiva
 21 Siddha 22 Sādhyā 23 Shubha 24 Shukla 25 Brahmā 26
 Andra 27 Vaidhṛti

The Repeating Karanas

Their Numbers								Names
2	9	16	23	30	37	44	51	Bava
3	10	17	24	31	38	45	52	Bālava
4	11	18	25	32	39	46	53	Kaulava
5	12	19	26	33	40	47	54	Taitila
6	13	20	27	34	41	48	55	Gara
7	14	21	28	35	42	49	56	Vanija
8	15	22	29	36	43	50	57	Bhadra

The Fixed Karanas

- 58 Shakuni 59 Nāga 60 Chatuspāda
 1 Kinstughna

TABLE 39

Supplementary to Table 5

(Based on the *Sūrya-Siddhānta*).

Increase of Elements to be used in verification.

Tithi.	Vāra	Days.	C's anom.	O's anom.	Tithi.	Vāra	Days.	C's anom.	O's anom.
11	3.83	10.83	141.5	10.7	21	6.65	20.67	270.0	20.4
12	4.81	11.81	151.3	11.6	22	0.66	21.66	282.9	21.3
13	5.80	12.80	167.2	12.6	23	1.64	22.64	295.8	22.3
14	6.78	13.78	180.0	13.6	24	2.62	23.62	308.6	23.3
15	0.76	14.76	192.9	14.6	25	3.61	24.61	321.5	24.2
16	1.75	15.75	205.8	15.5	26	4.59	25.59	334.4	25.2
17	2.73	16.73	218.6	16.5	27	5.58	26.58	347.2	26.2
18	3.72	17.72	231.5	17.5	28	6.56	27.56	360.1	27.2
19	4.70	18.70	244.3	18.4	29	0.54	28.55	12.9	28.1
20	5.69	19.69	257.2	19.4	30	1.53	29.53	25.8	29.1

TABLE 40

For conversion of fractions of a Day into Ghatīs and Palas

Continues	0	1	2	3	4	5	6	7	8	9
	g p	g p	g p	g p	g p	g p	g p	g p	g p	g p
.00	0 0	0 36	1 12	1 48	2 24	3 0	3 36	4 12	4 48	5 24
.10	6 0	6 36	7 12	7 48	8 24	9 0	9 36	10 12	10 48	11 24
.20	12 0	12 36	13 12	13 48	14 24	15 0	15 36	16 12	16 48	17 24
.30	18 0	18 36	19 12	19 48	20 24	21 0	21 36	22 12	22 48	23 24
.40	24 0	24 36	25 12	25 48	26 24	27 0	26 36	28 12	28 48	29 24
.50	30 0	30 36	31 12	31 48	32 24	33 0	33 36	34 12	34 48	35 24
.60	36 0	36 36	37 12	37 48	38 24	39 0	39 36	40 12	40 48	41 24
.70	42 0	42 36	43 12	43 48	44 24	45 0	45 36	46 12	46 48	47 24
.80	48 0	48 36	49 12	49 48	50 24	51 0	51 36	52 12	52 48	53 24
.90	54 0	54 36	55 12	55 48	56 24	57 0	57 36	58 12	58 48	59 24
For Mille- sims	0 0	0 4	0 7	0 11	0 14	0 18	0 22	0 25	0 29	0 32

Example:—Sec. 82. Type of Cal: 0.204 day. Of this .20 = 15 gh
20 p, and .004 = 14 palas. So 0.204 day = 15 gh 20 p

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APPENDIX II

Note on the longitude of the star Spica

The following two verses, which are quoted from Garga Samhitā by Somāhara the commentator of Vedānga Jyotiṣha clearly show the fact that the longitude of the star Spica was 180° in the ancient Hindu Zodiac. Its division into 27 equal parts called nakṣatras, was made with respect to the star α Delphin which was used as a starting point in the matter of sidereal division

यदा माघस्य शुक्लस्य प्रतिपद्युत्तरायण ।

सहोदय भविष्यामि एषार्कं प्रतिपद्यतः ॥

तदाञ्च नमस शुक्लसप्तम्या दक्षिणायन ।

राशेर्धि कुरुते युक्ति चित्राया च निक्षपदे ॥

By the use of the plural word भविष्यामि the author means the chief star of the cluster. The verses mean that when on the first day of माघशुक्ल the sun and the moon arrive together at the winter solstitial point marked by the star α Delphin, the next summer solstice takes place on the 7th day of the bright half of the month १५२ the sun being then at the middle point of the division सप्त and the moon in conjunction with the star चित्रा (Spica)

This description undoubtedly means that the distance of the star Spica from the star Alpha Delphin is equal to the mean motion of the moon in six tropical months, that is in 182 days 37 ghatis and 16 palas. Now the best modern tables give for the moon's motion during this period $246^\circ 17' 2''$. Deducting from this the distance of α Delphin to the first point of Ashvini which is equal to $13^\circ 20' \times 5 = 66^\circ 40'$, we get $179^\circ 37' 2''$ for the longitude of Spica which in round number was said to be 180° .

This result can also be arrived at independently in another way. The sidereal longitude of α Delphin is $13^\circ 20' \times 22 = 293^\circ 20'$. Deducting from this the distance from Spica to α Delphin, which is by my Jyotiṣgāṇṭha p 232 $113^\circ 32' 6''$, there remains $179^\circ 47' 4''$ for the longitude of Spica which is almost 180 degrees.

The giving of names to the 27 divisions seems to have taken place about the year B. C. 2000, when the tropical longitude of the first point of the Ashvini division was 330° . The year of the Aryans and other ancient nations generally commenced when the sun's longitude was 330° . The Chinese still begin their year in that lunar month in which the sun arrives at the 330th the degree of tropical longitude.

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